ISSN 0376-477X

中華農業研究

第四十二卷 第二期

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中華民國八十二年六月
臺灣省農業試驗所出版
中華民國 臺灣省 臺中縣 霧峰鄉

中華農業研究（Jour. Agric. Res. China）42(2)：99～111（1993）

水稻期作與地區間產量及產量構成要素之品種間差異[1]

蔡　金　川[2]

摘要：本試驗以秈稉稻各十五個品種爲材料，分別於臺北及臺中地區進行兩期作之田間試驗，調查各品種之抽穗期，並於成熟期測定產量與產量構成要素。目的在探討水稻品種於不同期作或地區間，對於產量及產量構成要素之表現狀況，及其品種間之差異，所得試驗資料，可供育種家之參考應用。

由試驗結果得知，秈稉型品種第一期作之產量高於第二期作，臺中大於臺北地區。產量及產量構成要素之期作間或地區間之差異，及品種間差異皆達1%水準的顯著性差異。其他之交感作用大部分亦極顯著。而產量構成要素方面除了千粒重之外，其餘與產量之變異並不一致。

不論期作或地區，表現高產品種爲臺農67號（Tainung 67）、臺南5號（Tainan 5）、臺東29號（Taitung 29）、臺中秈10號（Taichung Sen 10）及嘉農秈11號（Chianung SEN 11），而期作性豐收之品種，第一及第二期作分別爲臺農62號（Tainung 62）、高雄秈7號（Kaohsiung Sen 7）與豐錦（Toyonishiki）、臺農秈12號（Tainung Sen 12）。這些品種大部分屬於穗數型。穗數之環境（期作、地區）間之品種相關係數皆爲正相關，表示穗數對不同環境有較穩定性之表現。

關鍵詞：產量、產量構成要素、期作。

臺灣之水稻栽培一般爲兩期作，據臺灣農業年報(10)之統計，其耕作面積約45萬公頃，第一期作24萬公頃，第二期作21萬公頃，每公頃糙米（unpolished rice）之產量第一期作約4,000公斤，第二期作約3,500公斤，即第二期作的產量較第一期作約低20%，類似之報告如林(1)、黃(6)、鄔等(8)及蔡(13)。又臺中地區的產量較臺北地區爲高。

此兩期作產量之差異，據以往的報告(1,7,8)可歸於環境條件、品種因素及栽培管理等所引起。環境條件裡氣象因子爲最重要的一項，首先有關氣溫狀況，臺灣各地之年平均氣溫除了高山之外，皆在21°C以上。水稻生育期間之最高氣溫不一定高。即顯現亞熱帶或熱帶氣候的特徵，日夜溫差及夏冬季間之氣溫差皆較小，而第一，二期作間氣溫差異亦不大。但各期作氣溫變化過程，第一期作之水稻生育由低溫時期至高溫時期，相反的第二期作自高溫到低溫時期(13)。

黃(7)及蔡(12)指出，第二期作生育初期因高溫與高日射量，分蘗易受抑制，則成熟期穗數減少。又翁(4)與劉(9)認爲高溫使抽穗前莖葉裡貯藏的同化生產物有降低的趨勢，抽穗後穀粒充實期之供源減少，影響產量的提升。而地區間產量之差異，主要亦由於氣候因子的影響，即臺中地區之氣溫、日照等比臺北地區較適合於水稻生育，因此臺中地區之稻作產量優於臺北地區。

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1. 臺灣省農業試驗所　研究報告第1661號。本報告承日本東京大學 Takeda Genkichi 教授指導及斧正，謹此致謝。
2. 本所農工系副研究員。臺灣省　臺中縣　霧峰鄉。

栽培管理方面，第一、二期作之挿秧期愈南部愈早、越往北部越遲。但不論那一地區，第一期作之收穫至第二期作之移植期間，較第二期作之收割到第一期作之挿秧期間爲短，前者爲10日～2週，後者是30日～40日。即前作後之作業期間，第二期作比第一期作更短，因此普通第二期作之耕耘、水管理等作業較粗放。

至於品種因素，臺灣水稻育種工作，向以全省爲一整體，於第一期作與第二期作連續選拔。但因第一、二期作的氣候條件不同，適合於第一期作栽培的水稻品種不一定能適應第二期作的氣候環境。因此本省的傳統育種方法實有重新檢討的必要。本報告爲連續性試驗研究之一，並不討論稻之分期或不分期育種之得失，採用之秈稉型各15個品種，大部份仍以本省實用品種爲材料，探討品種之產量與產量構成要素在不同期作或地區之反應，及其品種間之差異。所得資料可供分期或不分期高產品種育成之參考資料。而育種亦是緩和期作性及地區性產量差異有效途徑之一，以目前的育種方法，乃育成適應性較廣地區，或兩期作皆能適應之品種爲妥當。

材料與方法

本試驗以秈稉稻各15個品種爲材料，各品種名稱如下：

稉型 (Japonica type)

一、早熟品種 (Early Varieties)：(1)臺中186號 (Taichung 186) (2)高雄選1號 (Kaohsiung sel 1) (3)豐錦 (Toyonishiki)。

二、中熟品種 (Mediun Varieties)：(4)臺北309號 (Taipei 309) (5)臺農62號 (Tainung 62) (6)臺農67號 (Tainung 67) (7)嘉農242號 (Chianung 242) (8)臺南5號 (Tainan 5) (9)臺南6號 (Tainan 6) (10)高雄139號 (Kaohsiung 139)。

三、晚熟品種 (Late Varieties)：(11)新竹56號 (Hsinchu 56) (12)臺中65號 (Taichung 65) (13)嘉南8號 (Chianan 8) (14)高雄140號 (Kaohsiung 140) (15)臺東29號 (Taitung 29)。

秈型 (Indica type)

一、早熟品種 (Early Varieties)：(16)包葉菊 (Pao-yeh-tzu) (17)矮脚南特 (Ai-Chio-nan-te) (18)夾葉青8號 (Chia-Yeh-Ching 8) (19)珍珠矮11號 (Chen-tzu-ai 11) (20)南早32號 (Nan-tsao 32)。

二、中熟品種 (Medium Varieties)：(21)新竹矮脚尖 (Hsinchu-ai-chuch-chien) (22)臺中再來1號 (Taichung Native 1) (23)臺中秈2號 (Taichung Sen 8) (24)臺中秈10號 (Taichung Sen 10) (25)嘉農秈8號 (Chianung Sen 8) (26)嘉農秈11號 (Chianung Sen 11) (27)臺農秈12號 (Tainung Sen 12) (28)高雄秈7號 (Kaohsiung Sen 7)。

三、晚熟品種 (Late Varieties)：(29)臺中秈3號 (Taichung Sen 3) (30)嘉農秈6號 (Chianung Sen 6)。

本試驗以上記之秈稉稻各15個品種爲材料，1981年第一期作及1980年第二期作同時於臺北地區（臺灣大學附屬試驗農業）與臺中（臺中縣霧峰鄉本所試驗農場）同時進行栽培試驗。第一期作之挿秧日期在臺北與臺中分別爲3月10日及2月14日，第二期作分別爲8月4日及7月28日。行株距爲25*20cm，採多本植，小區面積爲8 m²，重複三次，採用逢機完全區集設計。肥料（N：P_2O_5：K_2O）用量在第一期作爲134：58：54kg/ha，第二期作爲122：45：51kg/ha，其他栽培管理依一般慣行法行之。

水稻生育期間調查抽穗日數（移植至抽穗期之日數），抽穗後至成熟期之穀粒充實日數，並於成熟期每小區取10株，每品種一共30株烘乾後測定產量及產量構成要素。

結 果

有關產量及產量構成要素之期作、地區及品種效應之變方分析結果列表1。由 F 值測定得知，各性狀之各變因（期作、地區及品種）效應皆達1%水準之顯著性差異，顯示這些性狀之期作間、地區間及品種間皆有顯著之差異存在。至於交感作用方面，除了稻穀產量性狀之地區與期作之交感效應（L＊C）外，其他各項性狀之交感作用亦達顯著性水準，而水稻生育期之氣象條件（氣溫、日射量）請參照前報[13]之圖1。

表1. 臺北及臺中地區稉型與秈型水稻品種之產量及產量構成要素之變方分析

Table 1. Analysis of variance for grain yield and yield components for Japonica and Indica rice cultivars cultivated in Taipei and Taichung areas

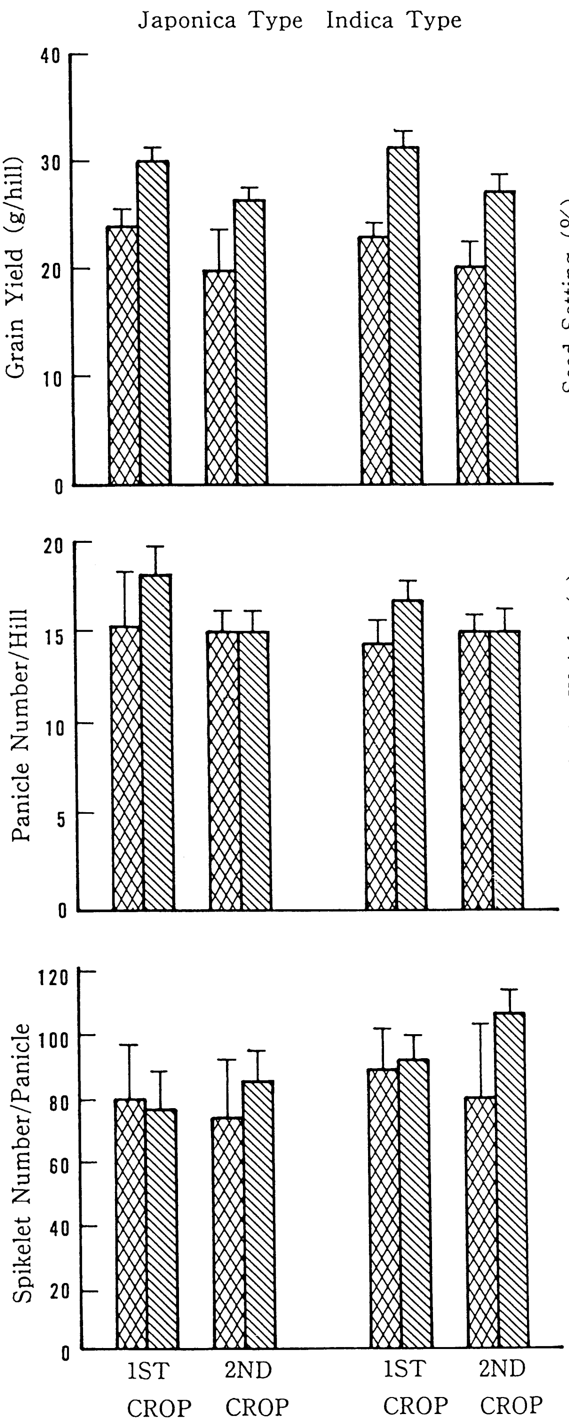
Soure of Variation	df	Grain Yield per Hill	Panicle Number per Hill	Spikelet No. per Panicle	Seed Setting Rate	1,000 Grain-Weight
		Mean square				
Cuop (C)	1	1282.22**	84.50**	459.16**	2100.66**	156.87**
Location (L)	1	4101.91**	134.16**	6927.69**	291.42**	312.93**
L x C	1	0.41	111.63**	7920.94**	748.63**	11.69**
Error	8	1.06	0.43	42.20	1.56	0.44
Variety (V)	29	22.93**	11.59	793.30**	125.67**	12.86**
Japonica	14	22.54**	8.02	351.42**	45.24**	12.93**
Indica	14	24.78**	14.08**	385.83**	19.97**	11.16**
Japonica VS Indica	1	2.57*	26.62**	11814.23**	2723.53**	35.71**
C x V	29	4.56**	3.11**	107.67**	27.15**	3.01**
L x V	29	9.85**	1.35**	182.44**	57.31**	1.66**
Error	261	0.66	0.56	14.94	2.92	0.41

* and ** are significant at 5% and 1% levels, repectively.

1. 期作間或地區間產量及產量構成要素之差異：

秈稉型各十五個品種之平均作示於圖1。由此圖所示，首先關於單株稻穀產量方面，無論地區，或期作，兩型（秈稉）品種皆爲第一期作之產量高於第二期作。臺北地區低於臺中地區，而稉型品種大於秈型品種。

產量構成要素方面，有關一株穗數臺北地區之秈型品種，第一期作小於第二期作，而第二期作兩型品種兩地區（臺北、臺中）之穗數相似，其他與產量之變化趨勢相同。一穗穎花數及結實率在品種型、地區或期作間缺少完全一致的變化趨勢，因兩性狀間具有互補作用，即一穗穎花數低者，其結實率常較高。就一穗穎花數而言，臺北地區第一期作高於第二期作，臺中地區的表現相反，即第一期作低於第二期作；第二期作秈型品種顯著以臺中地區爲高，是導致地區間產量差異的最主原因。其他千粒重之變化趨勢與產量一致。



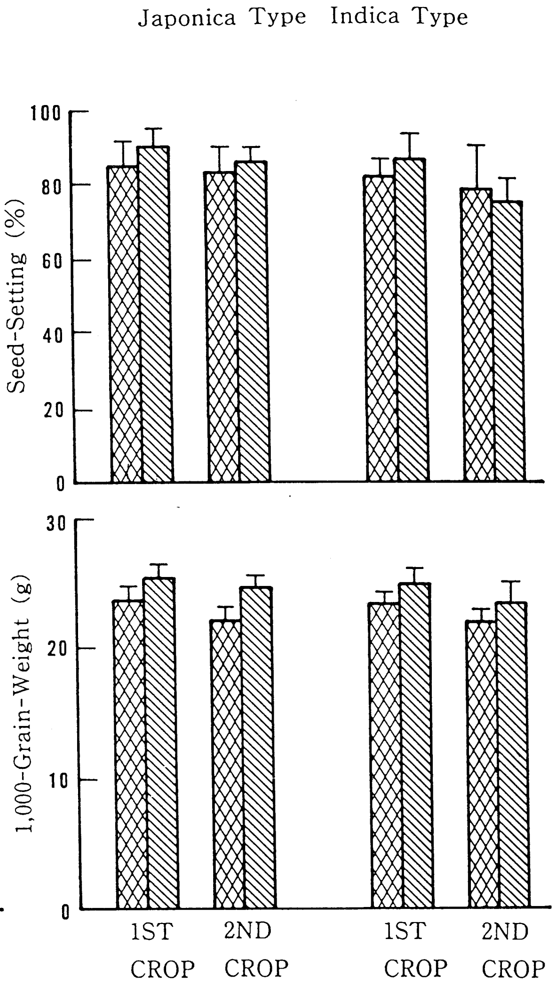


圖 1. 臺北及臺中地區水稻品種之產量及產量構成要素 (15品種之平均值)

Fig. 1. Grain yield and yield components of rice cultivars cultivated in Taipei (▩) and Taichung (▨) areas. Results are means of 15 cultivars.

其次是環境間之品種相關係數（表2），兩型品種之產量，期作間皆呈現顯著之正相關，而地區間之相關係數較低，顯示這些性狀之期作間、地區間及品種間，皆有顯著之差異存在，這表示對於產量期作間有顯著之密切關係，而地區間無明顯關係存在。此可當爲水稻品種適應性選拔方法之參考依據。產量構成要素之相關係數較複雜，不呈現一定的趨勢，只有臺北地區期作間表現較高的顯著性正相關，其餘相關之穩定性較弱。

表2. 稉型及秈型水稻產量及產量構成要素之期作間（第一及第二期作）與地區間（臺北及臺中）之品種相關係數

Table 2. Correlation coefficients of yield and yield components of Japonica and Indica rice cultivars between crops seasons (1st and 2nd crops) and between locations (Taipei and Taichung)

Cultivar	Grain Yield per Hill	Panicle Number per Hill	Spikelet No. per Panicle	Seed-Setting Rate	1,000 Grain Weight
Japonica					
Between Crops					
Taipei	0.78**	0.60*	0.74**	0.97**	0.89**
Taichung	0.70**	0.46	0.64**	0.40	0.40
Between Locations					
1st Crops	0.45	0.52*	0.61*	0.16	0.72**
2nd Crops	0.50	0.79**	0.46	−0.04	0.41
Indica					
Between Crops					
Taipei	0.62**	0.86**	0.55**	0.47	0.69**
Taichung	0.65**	0.19	−0.04	0.16	−0.02
Between Locations					
1st Crops	0.43	0.89**	0.69**	−0.45	0.95**
2nd Crops	0.48	0.29	−0.10	−0.13	0.58*

* and ** are significant at 5% and 1%, respectively

2. 產量及產量構成要素之品種間差異：

不論期作或地區皆表現高產之品種，稉型有臺農67號（Tainung 67）、臺南5號（Tainan 5）及臺東29號（Taitung 29）三品種（表3及表4），秈型則臺中秈10號（Taichung Sen 10）及嘉農秈11號（Chianung Sen 11）（表5、表6）。其他臺農62號（Tainug 62）、高雄秈7號（Kaohsiung Sen 7）與豐錦（Toyonishiki）、臺農秈12號（Tainung Sen 12），分別爲第一期作及第二期作豐產，爲期作性高產之品種。

各品種間對於產量構成要素之變動性較大，無一品種在這方面有較穩定的表現。如臺農67號（Tainung 67）不論在那種環境下，皆出現較多的穗數，屬於穗數型。而臺中在來一號（Taichung Native 1）及第一期作之豐錦（Toyonishiki）、臺農秈12號（Tainung Sen 12），因一穗穎花數的減少，使產量降低。但如嘉農242號（Chianung 242）、嘉南8號（Chianan 8）及矮脚南特（Ai-Cho-Nan-Te）一穗穎花數較多，而其他產量構成要素較低、致使產量亦減低。其他如臺中186號（Taichung 186）、臺農62號（Tainug 62）、夾葉青8號（Chia-yeh-ching 8）及嘉農秈8號（Chianung Sen 8）之千粒重表現頗爲獨特優異。

表3. 臺北及臺中地區粳型水稻品種之產量及產量構成要素

Table 3. Yield and yield components of 15 Japonica rice cultivars cultivated in Taipei and Taichung areas[1]

Cultivar	Crain Yield (g/m²)				Panicle No./m²				Spikelet No./Panicle				Seed-Setting Rate (%)				1,000-Grain-Weight (ε)			
	1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop	
	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC
Early Varieties																				
1. Taichung 186	487bcd	551hi	437ab	525def	308defg	332ef	290fg	274de	78.9c	72.7e	79.1b	74.2g	81.2g	88.5e	79.8h	94.4a	24.8b	25.8bcd	23.8b	27.4a
2. Kaohsiung S. 1	414h	587ef	379d	524def	298fg	328fg	306cde	310abc	76.3cdef	83.5b	72.2de	84.9de	81.1g	84.9de	80.4h	82.2de	22.5hi	25.2bcde	21.4efg	24.3cde
3. Toyonishiki	475cde	593def	438ab	545bcde	338a	378bc	320ab	308abc	70.1h	6837g	70.5efg	77.2fg	85.5abc	93.4ab	85.1a	94.3a	23.5defg	24.5cde	22.9c	24.3cde
Medium Varieties																				
4. Taipei 309	503bc	590ef	417bc	522defg	302efg	338def	300def	324ab	85.9ab	76.2d	77.3bc	79.8efg	84.0de	88.3e	82.9de	85.1c	23.2efgh	26.0bc	21.7ef	23.7def
5. Tainung 62	502bc	639b	414c	512efg	328ab	364bcd	300def	302bcde	70.4gh	71.6ef	66.9h	80.8defg	84.3bcd	87.9e	83.7cd	82.8cde	25.8a	27.9a	24.7a	25.3bc
6. Tainumg 67	535a	669a	457a	604a	326abc	372bc	326a	336a	78.1cd	81.8bc	70.4efg	85.5cde	85.7ab	86.5f	84.9a	83.0cde	24.5bc	25.4bcde	23.5bc	25.3bc
7. Chianung 242	464def	546i	379d	491gh	270h	300g	284g	282cde	87.3a	81.2c	77.7bc	87.3bcd	82.7ef	91.9c	81.3g	80.5e	23.8cdef	24.3def	21.1fgh	24.7cd
8. Tainan 5	502bc	632b	421bc	559bc	308cdef	356cdef	286g	286cde	82.9b	81.1c	83.2a	93.3ab	86.2a	87.4ef	85.2a	80.8e	22.8gh	25.1bcde	20.8ghi	25.9b
9. Tainan 6	496bc	603de	387d	533cdef	306defg	348cdef	306cde	306abcd	78.5c	79.8c	68.9fgh	85.2de	86.0a	88.4e	84.7ab	83.7cd	24.1bcd	24.6cde	21.7ef	24.4cde
10. Kaohsiung 139	431gh	594def	354e	554bcd	294fg	410a	316abc	314abc	74.9def	63.8h	67.5gh	81.0defg	84.2cd	94.0a	82.2ef	89.6b	23.2defgh	24.1ef	20.2ij	24.4cde
Late Varieties																				
11. Hsinchu 56	494bc	563gh	391d	469h	298efg	354cdef	296efg	270e	83.9b	70.0fg	71.6ef	92.4abc	84.3bcd	92.4bc	83.3cd	82.3de	23.5defg	24.7cde	22.4cde	22.9f
12. Taichung 65	463def	578fg	383d	508fg	318bcde	368bc	300def	314abc	73.6fg	64.0h	68.3gh	79.2efg	80.6g	92.5bc	79.7h	84.0cd	24.6bc	26.6ab	23.4bc	24.4cde
13. Chianan 8	446efg	565gh	375de	511fg	288gh	336de	292fg	270e	87.6a	88.7a	82.4a	98.8a	81.2fg	82.7h	79.8h	81.5de	21.8i	22.9f	19.5j	23.5ef
14. Kaohsiung 140	437fgh	612c	329f	522defg	306cdefg	392ab	312bcd	314abc	74.1ef	70.3fg	63.5i	81.0defg	83.8de	90.5d	81.5fg	82.2de	23.0fgh	24.6cde	20.4hi	25.0bc
15. Taitung 29	511b	609cd	456a	566b	336abcd	358cde	316abc	334ab	76.9cde	69.7fg	75.0cd	83.2def	85.1abcd	88.4e	84.0bc	80.6e	24.0bcde	27.7a	22.9cd	25.3bc
Mean	477	595	404	530	308	356	303	303	78.6	74.9	73.0	84.3	83.7	89.2	82.6	84.5	23.7	25.3	22.0	24.7
SD	34.0	33.8	37.1	32.8	18.5	27.3	12.7	21.9	5.75	7.48	5.89	6.56	1.92	3.23	2.04	4.60	1.01	1.34	1.49	1.07
CV (%)	7.13	5.68	9.25	6.19	6.01	7.67	4.19	7.23	7.32	9.99	8.07	7.78	2.29	3.62	2.47	5.44	4.26	5.30	6.79	4.34

1. Means with the same letter within each column are not significantly different at 5% level by Duncan's multiple range test.
2. TP : Taipei;TC : Taichung.

表4. 臺北及臺中地區稉型水稻品種間產量及產量構成要素之順位表

Table 4. Orrder of performance in grain yield and yield components of 15 Japonica rice cultivars grown in Taipei and Taichung areas.

Cultivar	Crain Yield (g/m²)				Panicle No./m²				Spikelet No./Panicle				Seed-Setting Rate (%)				1,000-Grain-Weight (ε)			
	1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop	
	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC
Early Varieties																				
1. Taichung 186	8	14	4	7	7	13	13	11	6	8	3	15	12	7	13	1	2	5	2	1
2. Kaohsiung S. 1	15	10	12	8	12	14	7	5	10	2	7	7	13	14	12	11	14	7	10	12
3. Toyonishiki	9	8	3	5	1	3	2	6	15	13	9	14	4	2	2	2	8	12	5	11
Medium Varieties																				
4. Taipei 309	3	9	6	10	10	11	8	3	3	7	5	12	8	10	8	4	11	4	9	13
5. Tainung 62	4	2	7	11	2	6	10	8	14	9	14	11	6	11	6	8	1	1	1	4
6. Tainumg 67	1	1	1	1	3	4	1	1	8	3	10	5	3	13	3	7	4	6	3	5
7. Chianung 242	10	15	11	14	15	15	15	10	2	4	4	4	10	5	11	15	7	13	11	7
8. Tainan 5	5	3	5	3	6	8	14	9	5	5	1	2	1	12	1	13	13	8	12	2
9. Tainan 6	6	6	9	6	9	10	6	7	7	6	11	6	2	8	4	6	5	10	8	8
10. Kaohsiung 139	14	7	14	4	13	1	4	4	11	15	13	9	7	1	9	3	10	14	14	10
Late Varieties																				
11. Hsinchu 56	7	13	8	15	11	9	11	13	4	11	8	3	6	4	7	9	9	9	7	15
12. Taichung 65	11	11	10	13	5	5	9	4	13	14	12	13	14	3	14	5	3	3	4	9
13. Chianan 8	12	12	13	12	14	12	12	12	1	1	2	1	11	15	13	12	15	15	15	14
14. Kaohsiung 140	13	4	15	9	8	2	5	4	12	10	15	10	9	6	10	10	12	11	13	6
15. Taitung 29	2	5	2	2	4	7	3	2	9	12	6	8	5	9	5	14	6	2	6	3

TP : Taipei;TC : Taichung.

表5. 臺北及臺中地區秈型水稻品種之產量及產量構成要素

Table 5. Yield and yield components of 15 Indica rice cultivars cultivated in Taipei and Taichung areas1

Cultivar	Crain Yield (g/m²)				Panicle No./m²				Spikelet No./Panicle				Seed-Setting Rate (%)				1,000-Grain-Weight (ε)			
	1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop	
	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC
Early Varieties																				
16. Pao-Yeh-Tzu	391h	581e	363gh	537defg	268fg	302fg	284g	294cde	80.4d	93.5bcd	73.2fg	107.8abc	81.6d	84.3abcd	80.9ab	73.7bcdef	22.3ef	24.5cdefg	21.5ef	23.2de
17. Ai-Cho-Nan-Te	448f	604de	389def	516efgh	252h	294g	268h	300cde	101.0a	106.5a	88.0b	107.0abc	80.6e	82.4bcd	78.9de	69.2f	21.9ef	23.4efg	20.9g	23.3de
18. Chia-Yeh-Ching 8	444f	650ab	372fhg	552cde	294cd	324cdef	294ef	318abcd	79.6d	91.7cde	70.8hg	92.6de	80.4e	86.2abc	79.8bcd	76.4abc	23.6d	25.3bcd	22.3cd	24.6abc
19. Chen-Tzu-Ai 11	451ef	618cd	378efg	501gh	278ef	330cde	300e	292cde	91.4bc	90.6cdef	74.0ef	97.8cde	78.5fg	86.7abc	78.5de	75.0bcd	22.5e	23.9defg	21.8ef	23.4cde
20. Nan-Tsao 22	413g	578e	377efgh	525defgh	252h	304efg	242efg	300bcde	90.6c	86.4efg	93.0a	89.5e	77.8g	89.2a	73.4g	79.7a	23.4d	24.6cdef	22.8bc	24.5abc
Medium Varieties																				
21. Hsin-Chu-Ai-Chueh-Chien	506ab	602de	413bc	456i	284de	314defg	290fg	254f	93.8b	100.7bcd	94.6a	108.6abc	85.9a	82.6bcd	72.3g	72.0cdef	22.1ef	23.1fg	20.8g	22.9def
22. Taichung Native 1	463de	647abc	377efg	542def	320b	392a	328a	348a	79.3d	84.7fg	73.9ef	91.6e	83.9bc	82.9bcd	79.5bcd	75.9abcd	21.7f	23.6efg	19.6h	22.4ef
23. Taichung Sen 2	449ef	607de	358h	492hi	296c	350bc	308cd	296cde	80.0d	91.8cde	75.1def	105.9bcd	85.8a	82.1cd	80.4bc	71.5def	22.1ef	23.0g	19.2h	22.0of
24. Taichung Sen 10	502b	659a	454a	637a	318b	388a	322ab	270ef	81.3d	81.8gh	77.4cd	120.2a	80.1e	80.9d	79.2cd	77.7ab	24.3bc	25.6bc	23.0ab	25.2a
25. Chianung Sen 8	503b	608de	398cd	525defgh	278ef	302fg	296ef	304cde	91.8bc	84.8defg	76.1de	108.2abc	76.1h	87.4ab	75.2f	71.5def	25.9a	27.3a	23.6a	22.3ef
26. Chianung Sen 11	518a	662a	417b	587bc	296cd	336cd	314c	330abc	93.8b	95.9bc	79.0c	97.2cde	78.9f	84.4abcd	77.6e	76.4abc	23.7cd	24.4cdefg	21.7ef	24.0bcd
27. Tainung Sen 12	485c	649ab	445a	600ab	336a	368ab	322ab	338ab	74.4e	82.8g	73.5efg	97.1cde	83.3c	86.3abc	82.3a	73.8bcdef	23.4d	24.7cde	22.9b	24.8ab
28. Kaohsiung Sen 7	510ab	657ab	395de	559cd	258gh	308defg	298ef	310bcd	99.7a	99.4b	74.9def	107.2abc	84.3b	86.5abc	82.0a	70.3ef	23.5b	24.8cde	21.6ef	23.9bcd
Late Varieties																				
29. Taichung Sen 3	466d	625bcd	335i	548cde	312b	376ab	316bc	282def	81.1d	72.1i	68.8h	117.6ab	75.2i	86.7abc	72.3g	73.0cdef	24.6b	26.6ab	21.3fg	22.6ef
30. Chianung Sen 6	486c	539f	405bcd	506gh	296cd	324cdef	302de	320abc	80.0d	75.9hi	77.2cd	96.3cde	80.9de	82.3bcd	79.6bcd	74.9bcde	25.4a	26.7ab	21.8de	21.9f
Mean	469	619	392	539	289	334	299	304	86.5	80.2	78.0	103.0	80.9	84.7	78.1	74.1	23.4	24.8	21.7	23.4
SD	37.1	35.7	31.9	45.4	25.5	33.1	22.4	25.0	8.38	9.36	7.73	9.23	3.29	2.45	3.31	2.90	1.29	1.33	1.21	1.06
CV (%)	7.91	5.77	8.14	8.42	8.82	9.91	7.49	8.22	9.69	10.50	9.91	8.96	4.07	2.89	4.23	3.91	5.50	5.35	5.59	4.54

1. Means with the same letter within each column are not significantly different at 5% level by Duncan's multiple range test.
2. TP : Taipei;TC : Taichung.

表6. 臺北及臺中地區秈型水稻品種間產量及產量構成要素之順位表

Table 6. Order of performance in grain yield and yield components of 15 Indica rice cultivars grown in Taipei and Taichung areas.

Cultivar	Crain Yield (g/m²)				Panicle No./m²				Spikelet No./Panicle				Seed-Setting Rate (%)				1,000-Grain-Weight (g)			
	1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop		1st Crop		2nd Crop	
	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC	TP	TC
Early Varieties																				
16. Pao-Yeh-Tzu	15	13	13	8	12	13	13	11	10	5	13	5	6	9	3	9	11	9	10	9
17. Ai-Cho-Nan-Te	12	11	8	11	14	15	14	9	1	1	3	7	8	12	9	15	14	13	12	8
18. Chia-Yeh-Ching 8	13	4	12	5	8	8	11	5	13	7	14	13	9	7	5	4	6	5	5	3
19. Chen-Tzu-Ai 11	10	8	9	13	10	7	8	11	6	8	10	9	12	4	10	6	10	11	7	7
20. Nan-Tsao 22	14	14	11	10	15	12	15	8	7	9	2	15	13	1	13	1	8	8	4	4
Medium Varieties																				
21. Hsin-Chu-Ai-Chueh-Chien	3	12	4	15	9	10	12	14	3	2	1	3	1	11	15	11	12	14	13	10
22. Taichung Native 1	9	6	10	7	2	1	1	1	14	11	11	14	4	10	7	5	15	12	14	12
23. Taichung Sen 2	11	10	14	14	5	5	6	10	12	6	8	8	2	14	4	13	13	15	15	14
24. Taichung Sen 10	5	2	1	1	3	2	2	13	8	13	5	1	10	15	8	2	4	4	2	1
25. Chianung Sen 8	4	9	6	9	11	14	10	7	5	10	7	4	14	2	12	12	1	1	1	13
26. Chianung Sen 11	1	1	3	3	7	6	5	3	4	4	4	10	11	8	11	3	5	10	8	5
27. Tainung Sen 12	7	5	2	2	1	4	3	2	15	12	12	11	5	6	1	8	9	7	3	2
28. Kaohsiung Sen 7	2	3	7	4	13	11	9	6	2	3	9	6	3	5	2	14	7	6	9	6
Late Varieties																				
29. Taichung Sen 3	8	7	15	6	4	3	4	12	9	15	15	2	15	3	14	10	3	3	11	11
30. Chianung Sen 6	6	15	5	12	6	9	7	4	11	14	6	12	7	13	6	7	2	2	6	15

TP : Taipei; TC : Taichung.

由以上之敍述概知，品種產量之高低，即產量之品種間差異，雖受產量構成要素所左右，但這些性狀無一定之變化趨勢。

討　論

由試驗結果得知，秈粳稻品種之產量於期作間或地區間皆有差異，本文以產量構成要素作爲探討其產量差異之要因，並探討品種於不同期作或地區對於上述性狀之表現狀況，如下列以分區作爲探討。

1. 臺北地區之期作間產量、產量構成要素差異之要因及其品種間之差異。

前報[13]曾指出第一期作水稻之生育經由低溫、低日射量至高溫、高日射量。因此生育初期受低溫之影響，移植後氣溫爲18°C左右。又日射量亦低約200cal/cm²/day，分蘗亦受抑制，又分蘗期延長以致無效分蘗增多。一般受害程度秈型品種較爲嚴重，成熟期之穗數亦比粳型品種較低，似乎粳型品種較耐低溫，特別是豐錦（Toyonishiki），臺農62號（Tainung 62）及臺農67號（Tainung 67）穗數較多，而秈稻臺農秈12號（Tainung Sen 12），臺中在來1號（Taichung Native 1）及臺中秈10號（Taichung Sen 10）號（Taichung Sen 10）之穗數亦較高，這些品種似乎具有耐低溫特性。

第一期作分蘗期之後天候漸好，至穀粒充實期平均氣溫及日射量各爲約28°C與300cal/cm²/day左右，水稻之生育及穀粒充實性良好，可能因此而導致第一期作之結實率及千粒重大於第二期作。據Tsai[19]之試驗結果知，乾物質生產性狀之總乾物重，LAI、LAD、CGR、NAR幾乎都比第二期作高，這些乾物質生產性狀絕大部份與產量呈現正相關，即這些性狀愈高則產量愈高的趨勢，此認爲第一期作之產量高於第二期作之原因。

其次第二期作低產之原因，生育初期遇高溫，因此分蘗受抑制，穗數減少，同時一穗穎花數亦降低；陳[5]、黃[7]、郞[6]及蔡[12]等曾有類似之報告。但本試驗結果（圖1），粳型品種之平均穗數兩期作相似，秈型品種第一期作之平均應穗數反而低於第二期作，據蔡[12]之研究報告指出，可能秈粳型品種對於氣溫反應差異所致。大部份較穩定之高產品種如粳稻臺農67號（Tainung 67）、臺東29號（Taitung 29）（表3與表4）及秈稻臺中秈10號（Taichung Sen 10）、嘉農秈11號（Chianung Sen 11）穗數較高（表5與表6），則分蘗期耐高溫之品種即較有可能豐收。

尙且第二期作生育初期因高溫及高日射量，水稻生產旺盛，營養生長期間有縮短的可能，由前報[13]得知，秈粳稻中熟品種嘉農秈11號及臺農67號之第一期作的平均生育日數分別爲131日與112日，即第二期作縮短19日。Vergara 等[21]認爲水稻營養生長可影響穗部的發育與充實，營養生育期愈長，則產量有愈高的趨勢；Tanaka and Vergara[20]的報告認爲如將水稻生育日數適當的延長至130～140日，與較短的生育期比較，產量均有增加。因此第二期作生育日數之縮短亦可說明產量低於第一期作之原因。事實上，除此之外，其他禾穀科作物也有相似的情況出現[16,17]。

又據翁等[4]及劉等[9]之試驗報告知，抽穗前儲藏於莖葉之同化產物，第一期作高於第二期作，加以第二期作抽穗後又遇低溫及低日射量，可能使光合成能力及光合成效率減低。基於上述理由，同化產物轉移至穀粒則有減少的可能。同時充實度之千粒重亦較結實率大幅降低。大部分之高產品種如豐錦（Toyonishiki）、臺農67號（Tainung 67）、臺東29號（Taitung 29）、臺中秈10號（Taichung Sen 10）與臺農秈12號（Tainung Sen 12）之千粒重皆有優異之表現。而翁等[3]之試驗報告，亦強調抽穗前儲藏於莖葉之碳水化合物乃抽穗後穗部之主要供源，綜言之，第二期作之減產乃抽穗前之高溫及抽穗後之低溫、低日射量之天候所致。

2. 期作間（臺中地區）、地區間（臺北、臺中地區）產量、產量構成要素差異之要因及其品種間之差異。

臺中地區第一期作移植後氣象條件與臺北相近，但分蘗期臺中之日射量約 260～300cal/cm²/day 較臺北（約200cal/cm²/day）爲高。鈴木[5]指出，氣溫暖和地區之分蘗期，遇到低氣溫若有充分的日射量，會影響穗數的增加。因此臺中地區第一期作之穗數高於第二期作，又高於臺北地區，主要因充分的日射量所致。這有助於葉面積指數的提昇，謝[14]曾述，第一期作自分蘗期至抽穗期，穗數與葉面積指數呈顯著性之正相關，即穗數的增加使葉面積指數有提昇的趨勢。又據蔡[19]指出，臺中地區第一期作之 LAI、LAD 及總乾物重高於第二期作及臺北地區，此亦可解釋期作間（臺中地區）及地區間（臺北、臺中）產量差異之原因。總而言之，臺中地區第一期作之產量高於第二期作及臺北地區，主要由於穗數所致。

而以中南部育成之品種高雄139號（Kaohsiung 139）、高雄140號（Kaohsi-ung 140）、臺中在來1號（Taichung Native 1）、臺中秈10號（Taichung Sen10）及臺中秈3號（Taichung 3）之穗數表現最爲優異。

其次第二期作生育初期兩地區之氣象條件相似，臺中地區平均氣溫約30°C，最高氣溫近35°C，分蘗亦受抑制，造成穗數的降低，而致少於第一期作。Tsai[19]認爲第二期作之乾物質生產性狀（總乾物重、LAI、LAD及CGR）不如第一期作，穗數之減少，爲其減產的主因。高產的品種臺農67號（Tainung 67）、臺東29號（Taitung 29）、嘉農秈11 號（Chianung Sen 11）與臺農秈12號（Tainung Sen 12）等（表3、表4、表5及表6）具有高穗數，可視爲分蘗期耐高溫之穗數型品種。

第二期作生育後期（抽穗至成熟期），臺中地區之平均氣溫（21～25°C）及日射量（270～310 cal/cm²/day）高於臺北地區（平均氣溫16～20°C），日射量(155～190cal/cm²/day)。據 Tsai[19]指出第二期作乾物質生產之氣象條件有利於臺中地區，因此成熟期之總乾物重及穀粒充實期之 CGR 大於臺北地區，又總乾物重及 CGR 與產量呈顯著之正相關。因此可認爲其產量高於臺北地區之原因。而高產品種臺農67號（Tainung 67）、臺南5號（Tainan 5）、臺東29號（Taitung 29）、臺中秈10號（Taichung Sen 10）、嘉農秈11號（chianung Sen 11）與臺農秈12號（Tainung Sen 12）之千粒重皆有良好表現，這是否與乾物質生產有關還待研究。

由以上之試驗結果及探討得知，兩地區（臺北、臺中）第二期作及臺北地區低產之要因，改善低產之對策以品種改良爲有效方法。以往臺灣水稻高產品種之育種方法，採用期作連續選拔及適應較廣地區之品系或品種，因此育成之品種臺農67號（Tainung 67)、臺南5號（Tainan 5)臺東29號（Taitung 29)、臺中秈10號（Taichung Sen 10）及嘉農秈11號（Chianung Sen 11），不論期作或地區皆表現高產，爲穩定性較大之品種，其大部分屬於穗數型，而穗數之環境（期作、地區）間品種相關係數皆爲正相關，即對於環境的變動之表現較穩定，因此穗數可認爲是高產品種選拔之指標。而上述之品種，可當作高產品種育成之雜交育種的親本。據 Tsai[19]曾進行全互交試驗發現，臺農67號及臺中秈10號具有產量、產量構成要素與乾物質生產性狀較高之一般組合力（GCA）。以這兩品種爲親本進行雜交育種，所育成高產之新品種臺農70號[11]及臺秈1號[2]。

除此之外，可能還決定於乾物質生產能力之影響。換言之，由品種之乾物質生產特性與其產量構成要素之相互作用的不同表現，則形成產量之品種間差異。

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Varietal Difference in Yield and Yield Component of Rice in Response to Crop Seasons and Regions[1]

J. C. Tsai[2]

Summary

Fifteen each of Japonica and Indica rice cultivars were grown under natural conditions in both the 1st and 2nd crop seasons at Taipei and Taichung. Heading data was investigated. Yield and yield component in maturing stage were also calculated, The purpose was to investigate the varietal difference in yield and yield compoment between crop seasons and between locations. Based on the information, it could be utilized as breeding programs.

Experimental results indicated that grain yield was higher for the 1st crop than for the 2nd crop, and higher at Taichung area than Taipei area. Yield and yield component were all significant at 1% level when the comparison were made among varieties, and between crop seasons, and between areas. Interaction between types, crop seasons and locations had also been detected, indicating significantly environmental impacts on the yield and yield components. In addition to 1,000-grain-weight, the other three yield components did not correspond consistently to the variation of grain yield.

Five varieties, namely Tainung 67, Tainan 5, Taitung 29, Taichung Sen 10 and Chianung Sen 11 yielded better than other varieties regardless of location and crop season. It was found that the varieties with high yield were quite stable. For the varieties of high yield in corp season, there were Tainung 62, Kaohsiung Sen 7 and Toyonishiki, Tainung Sen 12 for the first and second crop respectively. They all belonged to the panicle number type. And the positve correlations existed between crop seasons and between locations for the panicle number per hill, indicating stable responses to the environments.

Key words : Yield, Yield component, Crop season.

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1. Contribution No 1661 from Taiwan Agricultural Research Institute.
2. Associate Researcher, Depart. of Agricultural Engineering, TARI, Wufeng, Taichug, Taiwan 413, ROC.

中華農業研究（Jour. Agric. Res. China）42(2)：112～120（1993）

水稻穗著粒密度之研究
I.穗著粒密度類型之分類、預測模式之建立及其相關性狀之探討[1]

吳永培　陳一心　陳隆澤[2]

摘要：本研究使用34個水稻品種（系）爲材料，探討穗著粒密度類型與相關性狀之關係，經以10個與穗著粒密度相關的性狀進行主成份分析，結果發現第一主成份（Z_1）主要與長度因子、二次枝梗因子和每穗粒數有關；第二主成份（Z_2）主要與穗重、一次枝梗因子和每穗粒數有關；第三主成份（Z_3）主要與穗軸長、一次及二次枝梗數、二次枝梗總粒數與每穗粒數之比值有關；至於第四主成份（Z_4）則主要與穗長、一次枝梗數及其平均粒數有關。接著並以前述四個主成份對二種不同方法 K（每穗粒數與穗軸長及一次枝梗總長之和的比值）、L（每10公分之單位穗長內所含粒數）所估算之穗著粒密度進行逐步迴歸分析，其中穗著粒密度 K 及 L 分別獲得4及2條預測模式，其複相關係數 R^2 值均在0.84以上，並以其中利用主成份數較少之2條迴歸模式 K_2（$=0.918Z_1-0.215Z_3$，$R^2=0.888$）和 L_3（$=0.808Z_1+0.374Z_2-0.358Z_4$，$R^2=0.920$）爲最佳穗著粒密度之預測模式。進而由穗著粒密度與各相關性狀之相關分析中，可知穗重、一次枝梗平均粒數、二次枝梗因子和每穗粒數等性狀較高之品種，其穗著粒密度愈高，但穗長、穗軸長和一次枝梗總長度等之長度因子較小。

由34個品種在第一及第二主成份平面上描點之分布圖中，發現不論以穗著粒密度 K 或 L估算方法爲依據時，其所進行之品種分類，均將34個品種分成七群，分屬於四種穗著粒密度型，即極低、低、中、高穗著粒密度等四類型。

關鍵詞：水稻、穗著粒密度、相關性狀、主成份分析、逐步迴歸分析、相關分析。

水稻生產係以穀粒產量爲目的，而穗之形態特性（穗相）則與穀粒產量有密切關係，因此掌握構成穗的各有關參考訊息，對於穗型和穗相之診斷是非常重要的。譬如在評估營養及環境對稻穗發育之影響時，可以穗性狀之表現，做爲推測參考之依據（Manaka and Matsushima 1971），尤其是穗著粒密度與穀粒產量和品質有密切的關係。因之，評估此一特性之表現，對水稻栽培及育種選拔工作將有所助益，是一值得探討之課題。

水稻穗著粒密度的表示方法相當繁多，諸如 Takezaki（1943）和 Chandraratna（1964）以單位穗長之穀粒數表示穗著粒密度，而 Kawari（1968）則以每10公分穗長中一次枝梗數的多寡表示之，Morimura（1971）更以一次枝梗長度的和與穀粒數之比值大小做爲表示方法，另外 Futsuhara et al.（1979a）曾以三種不同穗著粒密度估算方法，利用17個品種進行評估，發現以穀粒數與穗軸長及一次技梗總長度之和的比值，是最佳的表示方法，由以上可知，穗著粒密度受很多性狀的影響而變

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1. 臺灣省農業試驗所　研究報告第 1662 號。
2. 本所嘉義農業試驗分所助理、研究員、副研究員。臺灣省　嘉義市。

動，諸如每穗粒數、一次枝梗數、一次枝梗平均粒數、二次枝梗數、二次枝梗總粒數、穗長等，並且會因品種和環境之差異而有不同的影響（Futsuhara et al. 1979a, b; Manaka and Matsushima 1971）。至於這些性狀中，則以每穗粒數的研究最多，並且集中於與產量關係方面的探討，然而對於其他性狀彼此間的關係則少有研究（Morimura 1971）。

由於決定穗著粒密度之性狀相當多，且性狀間具有某種程度之相關，降低了這些性狀推定穗著粒密度之準確性，因此本研究乃利用 SAS（Statistic Analysis System）套裝統計程式進行主成份分析（Principal component analysis），將相關性狀綜合凝成爲少數幾個綜合變項，藉以消除性狀間之共線性關係，以探討各性狀在諸主成份中貢獻比例的大小，據此，再以各主成份對穗著粒密度進行逐步迴歸分析（Stepwise regression analysis）選擇主成份來建立合適的迴歸模式，以供推定穗著粒密度之用（Johnson and Wichern 1988）。另外，並進行穗著粒密度與各相關性狀之相關分析，了解穗著粒密度與各性狀之關係，以提供將來穗型研究及判斷時之參考。

材料與方法

本研究共使用34個品種（系）爲參試材料（表1），於民國81年一期作種植於嘉義農業試驗分所試驗田，採用逢機完全區集設計（RCBD）、三重複，每重複每品種（系）種植4行，每行6株，行株距25×20公分，每品種（系）每重複採取中間行4株，每株逢機調查3穗（約穗數的1/4），栽培管理及收穫調製依地區慣行法行之。此外，另調查對照之臺稉育10298號品系，作爲迴歸模式測試之用。

調查項目計有：穗重（A）、穗長（B），穗軸長（C）、一次枝梗數（D），一次枝梗平均粒數（E）、一次枝梗總長（F）、二次枝梗數（G）、二枝梗總粒數（H）、二次枝梗總粒數與每穗粒數之比值（I）、每穗粒數（J）等十項，至於穗著粒密度則以每穗粒數與穗軸長及一次枝梗總長之和的比值（K）及每10公分單位穗長所含粒數多寡（L）等二種方法表示之。

爲了解穗著粒密度與各相關性狀間的關係，以10個性狀之相關係數矩陣進行主成份分析。並依主成份分析結果，將標準化之各性狀值分別代入求得各主成份之特徵值作爲自變數，而與穗著粒密度進行逐步迴歸分析與相關分析；此外，二次枝梗總粒數與每穗粒數之比值，因係爲百分率資料，先經 $\mathrm{Sin}^{-1}\sqrt{p}$ 轉換後，再進行標準化工作。

表1. 供試材料品種（系）名稱和其穗著粒密度介量

Table 1. List of cultivars/lines used in this study and their panicle density parameters estimated

編號	品種名稱	穗著粒密度 K	穗著粒密度 L	編號	品種名稱	穗著粒密度 K	穗著粒密度 L
1	臺稉育 9473號	0.88	44.8	19	臺稉育 6698號	1.43	78.2
2	臺稉育 3492號	1.06	54.0	20	臺稉育 7415號	1.45	72.0
3	糯型無名種	1.09	60.8	21	臺稉育 8324號	1.45	67.5
4	臺稉育 1005號	1.17	64.9	22	臺稉育 6695號	1.47	69.5
5	臺稉 2號	1.17	56.6	23	臺稉育10044號	1.51	85.1
6	臺農 67號	1.20	56.9	24	臺稉育17731號	1.51	70.6
7	臺稉育13635號	1.22	59.6	25	臺稉育 8383號	1.52	70.2
8	臺稉育13671號	1.26	66.6	26	臺稉育16477號	1.53	73.6
9	臺稉育 4052號	1.30	67.3	27	臺稉育13281號	1.57	78.6
10	臺稉育13733號	1.32	64.7	28	臺稉育 4406號	1.59	73.7
11	臺稉育13365號	1.34	66.7	29	臺稉育 5031號	1.63	79.5
12	臺稉育 3732號	1.37	66.6	30	臺稉育 6278號	1.70	81.4
13	臺稉育 8472號	1.37	69.0	31	臺稉育 5103號	1.72	85.0
14	臺稉育13441號	1.38	71.8	32	臺稉育 6773號	1.74	84.9
15	臺農 70號	1.38	70.9	33	臺稉育 5107號	1.74	84.2
16	臺稉育19351號	1.39	65.5	34	臺稉育 6781號	1.77	87.3
17	臺稉育 5514號	1.41	68.5	CK	臺稉育10298號	1.34	69.4
18	臺稉育14467號	1.40	65.5				

結果與討論

一、34個品種（系）之主成份分析

如表2所示，以10個與穗著粒密度有關性狀所進行的主成份分析中，其第一（Z_1）、二（Z_2）、三（Z_3）和四（Z_4）主成份約各解釋了總變異的36、32、13和11%，累積四個主成份共解釋總變異的92%左右，而在其第一主成份中，以 A、E、G、H、I、J 性狀的係數爲正值，而 B、C、D、F 性狀的係數爲負值，並以 B、C、F、G、H、I 之係數具有較大的值，因此這一主成份主要與長度因子和二次枝梗因子有關。但在第二主成份中，除了 I 性狀的係數爲負值外，其餘性狀的係數則皆爲正值，並以 A、D、E、F、J 的係數具有較大的值，因此，這一主成份主要與穗重、一次枝梗因子和每穗粒數有關。在第三主成份中，B、C、D、F、G、H、I 性狀之係數爲正值，A、E、J 性狀的係數爲負值，而以 C、E、G、I 之係數具有較大的值，因此穗軸長、一次、二次枝梗數和二次枝梗總粒數與每穗粒數之比值與此主成份關係密切。至於第四主成份中，則以 A、B、C、E、H、I 性狀的係數爲正值，D、F、G、J 性狀之係數爲負值，而以 B、D、E 之係數具有較大的值，因此，穗長、一次枝梗數及其平均粒數爲左右此一主成份大小的主要性狀因子。

表2. 主成份係數和分析表

Table 2. Factor loadings of the first four principal compoments for 34 cultivars/lines

性狀[1]	主成分			
	Z_1	Z_2	Z_3	Z_4
A	0.223	0.447	−0.146	0.041
B	−0.326	0.273	0.192	0.506
C	−0.365	0.254	0.379	0.221
D	−0.136	0.357	0.054	−0.668
E	0.160	0.346	−0.458	0.405
F	−0.371	0.344	0.188	−0.077
G	0.310	0.093	0.604	−0.079
H	0.449	0.258	0.138	0.028
I	0.390	−0.169	0.401	0.242
J	0.283	0.438	−0.077	−0.106
特徵值	3.611	3.198	1.300	1.132
佔總變異之百分比	0.361	0.320	0.130	0.113
佔總變異之累積百分比	0.361	0.681	0.811	0.924

1)：A：Panicle weight
B：Panicle length
C：Length of rachis
D：Number of primary branches
E：Average number of spikelets per primary branch
F：Total length of primary branch
G：Number of secondary branches
H：Total number of spikelets of secondary branches
I：Total number of spikelets of secondary branches/Total number of spikelets per panicle.
J：Total number of spikelets per panicle

上述分析結果與 Kondo and Futsuhara (1980) 所得結果不盡相同，其原因可能是材料、調查性狀種類及數目不同所致，尤其是其所使用材料有部份來自於突變品系，因此可能造成與本研究所得

結果不同。

二、穗著粒密度之預測模式建立

利用34個品種所估計二種不同穗著粒密度介量 K 及 L ，進行它與各主成份值之間的相關分析，結果發現穗著粒密度介量 K 與第一主成份間之相關係數爲0.918**，達到極顯著水準，然而其與第二、三和四主成份間的相關係數各爲0.210、－0.215、－0.108，均不顯著，而穗著粒密度介量 L 則與第一、二及第四主成份均有相關關係，相關係數分別爲0.808**、0.374*、－0.358*，均達顯著水準，而與第三主成份的相關係數爲－0.215，則不顯著。而以各主成份對標準化的穗著粒密度進行逐步迴歸分析，得到緜性迴歸模式如表3所示，在穗著粒密度 K 及 L 的線性迴歸模式中，所有迴歸係數均達顯著水準，並且 K 的4條迴歸模式之複相關係數 R^2 值皆高於84%以上。至於迴歸模式中的 Z_1、Z_2、Z_3、Z_4 則是將經標準化之各性狀值分別代入表2各主成份的線性組合裡所得之新變項。

迴歸模式則利用臺稉育10298號品系進行測試，以此品系之各性狀平均值進行標準化後，再代入上述表2各主成份之線性組合中，求得前四項主成份之特徵值分別0.210、1.118、1.578、0.510，再各代入所建立的八條迴歸模式中（K_1-K_4，L_1-L_4；表3），求得穗著粒密度 K 的估值分別爲1.45（K_1）、1.38（K_2）、1.43（K_3）、1.42（K_4），與實際測量值1.43皆十分接近；而穗著粒密度 L 之估測值分別爲71.39（L_1）、75.91（L_2）、74.05（L_3）、70.61（L_4），與實際值69.4亦相當接近。顯示所建立之迴歸模式應具實用價值，唯本研究中由於僅以一品系進行測試，周延性似有不足，故有待進一步廣泛檢討，以確定其實用性。惟由於 K_2 這一條迴歸模式僅利用第一及二主成份，其 R^2 值即高達0.888，因此可選用此一迴歸模式，做爲穗著粒密度估測時之參考應用。至於穗著粒密度 L 的四條迴歸模式則以 L_2、L_3、L_4 具有較高的複相關係數值（R^2），而其中 L_3 迴歸模式只用了三個主成份，其 R^2 值即高達0.920，故可選用此一模式運用。亦即選用迴歸模式之複相關係數大於0.85且其參與之主成份最少的模式。

表3. 逐步迴歸分析之結果表

Table 3. The results of stepwise regression analysis

穗著粒密度		主成份變項[1] Z_1	Z_2	Z_3	Z_4	F值[2]	R^2
K	K_1	0.918				170.42	0.842
	K_2	0.918		−0.215		123.28	0.888
	K_3	0.918	0.210	−0.215		138.07	0.932
	K_4	0.918	0.210	−0.215	−0.108	122.37	0.944
L	L_1	0.808				60.12	0.653
	L_2	0.808	0.374			59.20	0.793
	L_3	0.808	0.374		−0.358	115.53	0.920
	L_4	0.808	0.374	−0.215	−0.358	209.73	0.967

1)：All regression coefficients significant at 1% level of probability, exclusive −0.108*.

2)：All F values significant at 1% level of probability.

由於本研究所調查的10個相關性狀間有高相關性存在（表略），若利用一般迴歸分析法來建立迴歸模式，其推定穗著粒密度能力就很低，但若先以主成份分析法把相關性很高的各性狀轉化成彼此互相獨立的主成份，消除了性狀間之共線性，再利用諸相關性狀之主成份值對穗著粒密度進行逐步迴歸分析，將使得推定穗著粒密度之準確性大幅提高，所以此法在資料轉換過程，雖然可能損失部份的訊息，

但仍是有利可行的（Hill et al. 1977）。不過本試驗採取此一方法，也給迴歸模式帶來一定程度的複雜性，較無法賦予迴歸模式實際意義的解釋。而其主成份之係數，則可以看作加權係數，這些加權係數的大小，亦是反映各個性狀的相對重要性之數量。

三、穗著粒密度與各相關性狀之簡單相關分析

由穗著粒密度與10個性狀間的相關分析中（表4）發現，在以穗著粒密度 K 爲表示方法中，除 D 性狀外，其餘9個性狀與穗著粒密度 K 間的相關係數，皆達極顯著水準，其中以 A、E、G、H、I、J 六個性狀與穗著粒密度間存有正相關關係，而 B、C、F、三性狀則有負相關關係，而在以穗著粒密度 L 爲表示方法的相關分析中，除與 D、I 二性狀間之相關係數不顯著外，與其餘8性狀間之相關係數皆達顯著水準。同樣的，穗著粒密度 L 與 A、E、G、H、J 性狀間亦爲正相關關係，而與 B、C、F 三狀間則爲負相關關係。

表4. 穗著粒密度介量 K、L 與其相關性狀間的相關分析結果

Table 4. Correlations between panicle density parameters estimated and its related characters of thirty four cultivars/lines

性狀[1]	K	L
A	0.565**	0.644**
B	−0.566**	−0.560**
C	−0.644**	−0.558**
D	−0.025	0.274
E	0.491**	0.435**
F	−0.587**	−0.357*
G	0.432**	0.406*
H	0.837**	0.831**
I	0.455**	0.300
J	0.671**	0.796**

1)：The same as Table 2.

*、**：Significant at 5% and 1% level of probability, respectively.

由此可知，穗重、一次枝梗平均粒數、二次枝梗數、二次枝梗總粒數和每穗粒數等性狀較高，而穗長、穗軸長、一次枝梗總長度等之長度因子較小的品種，其穗著粒密度也愈高，此結果與 Kondo and Futsuhara（1980）所得結果相吻合。

四、參試品種（系）之分類

利用第一及二主成份所具有之約68%的訊息，依各品種（系）之第一及二主成份值，將34個分別在第一及二主成分的平面上描點，其結果發現，依穗著粒密度之高低及圖上距離的遠近，在以穗著粒密度 K 之表示方法中，這34個品種（系），可歸類成七群，其中 I 群爲極低穗著粒密度型，穗著粒密度小於1.00，而 II、III 群爲低穗著粒密度型，穗著粒密度介於1.00～1.37之間，而 IV、V 群爲中穗著粒密度型，穗著粒密度介於1.38～1.51之間，而 VI、VII 群爲高穗著粒密度型，穗著粒密度大於1.52以上（圖1）。再者，在以穗著粒密度 L 之表示方法中，亦可將34個品種（系）歸類成七群，並定義 I′群爲極低穗著粒密度型，即每10公分單位穗長內粒數少於45粒者，而 II′群爲低穗著粒密度型，其粒數介於46～64粒之間，而III′、IV′群爲中穗著粒密度型，其粒數介於65～72之間；至於 V′、VI′、VII′群則爲高穗著粒密度型，其粒數大於73粒以上者屬之（圖2），其各群所包含之品種則如表5所示。

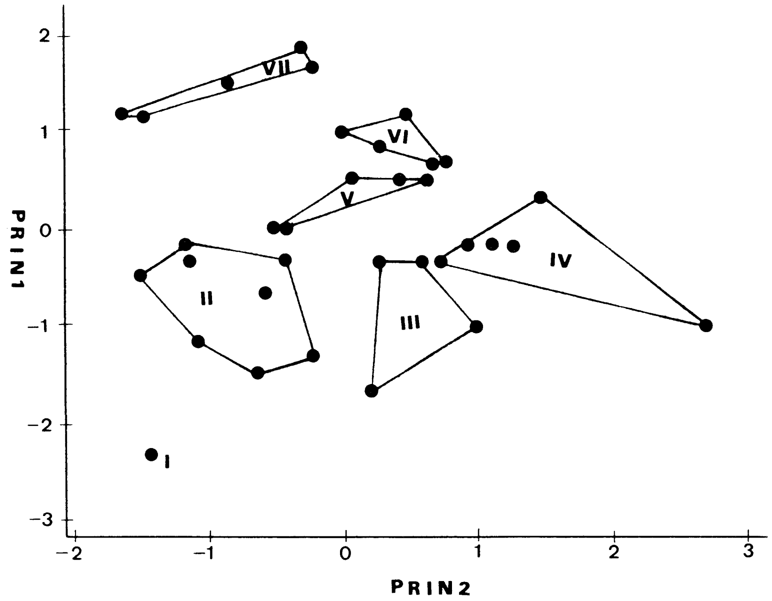

圖1. 第一、二主成份34個品種（系）之散佈圖；I —Ⅶ分類群代號。

Fig 1. Scatter diagram of 34 cultivars/lines on the plane defined by the first and second principal components; I —Ⅶ representing group number.

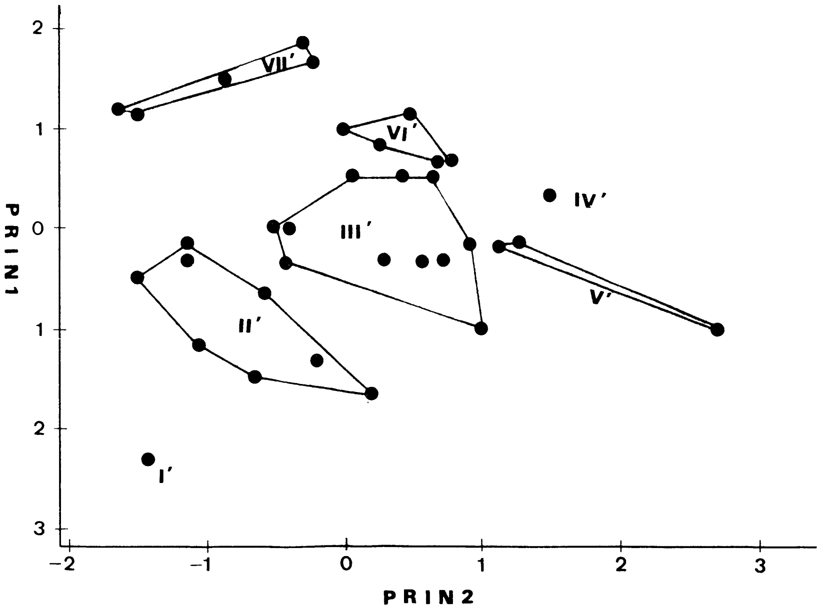

圖1. 第一、二主成份34個品種（系）之散佈圖；I '—Ⅶ'分類群代號。

Fig 1. Scatter diagram of 34 cultivars/lines on the plane defined by the first and second principal components; I '—Ⅶ' representing group number.

表5. 利用主成份分析法在34個品種分群之結果表

Table 5. The results of 34 cultivars/lines classified by principalcomponent analysis method.

穗著粒密度型	(範圍)	分類群代號	品種數目	品種代號[1)]
K	極低 (<1.00)	I	1	1
	低 (1.00—1.37)	II	8	2、4、5、6、7、8、12、13
		III	4	3、9、10、11
	中 (1.38—1.51)	IV	6	14、16、19、20、21、23
		V	5	15、17、18、22、24
	高 (>1.51)	VI	5	25、27、29、30、33
		VII	5	26、28、31、32、34
L	極低 (<45)	I′	1	1
	低 (46—64)	II′	8	2、3、4、5、6、7、12、13
		III′	1	9、
	中 (65—72)	IV′	13	8、10、11、14、15、16、17、18、20、21、22、24、25
		V	2	19、23
	高 (>73)	VI′	4	27、29、30、33
		VII′	5	26、28、31、32、34

1)：The same as Table 1.

上述分析結果，在以穗著粒密度介量 K 爲估算方法時，與 kondo and Futsuhara (1980) 所獲之結果大致相同，唯其分群範圍稍有差異。但若以穗著粒密度介量 L 爲估算方法時，本研究之結果則與 Manaka 和 Matsushima (1971) 所劃分者差異頗大，經比較兩研究之異同發現，Manaka 和 Matsushima (1971) 係以10公分單位穗長內其所含粒數，若在45粒以下者則爲疏型，介於46～60粒之間者爲中等型，而介於61～75粒之間者爲密型，76粒以上者則爲最密型，此種穗著粒密度類型之劃分方法，乃就主觀觀察所決定；而本研究係以主成份分析結果作爲分群歸類之依據，並非主觀判定，因此本研究之結果應較具客觀性，亦即對於品種類型之歸類，應有較合理準確性的劃分。

穗著粒密度之估算方法頗多，本研究以較常用的兩種方法進行穗著粒密度之估算，其結果發現兩種方法所估算之穗著粒密度間之相關係數爲0.925，已達極顯著水準；然而，兩種估算方法所得之品種分類結果並不一致，如臺稉育6698號品系，以穗著粒密度 K 估算，屬於中穗著粒密度型，但如以穗著粒密度 L 估算，則屬於高穗著粒密度型，唯由肉眼觀察，其應歸屬於中穗著粒密度型，因此可知以穗著粒密度 K 之估算方法，似與肉眼觀察結果較相近，然而由於穗著粒密度 L 之估算方法，僅須量取穗6的及每穗粒數，較簡便易行，亦是一種穗著粒密度估算的可行方法。

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Studies on the Panicle Density of Rice
I. Classification of panicle density types, establishment of prediction models and the correlations with related characters [1]

Y. P. Wu, Y. S. Chen and L. C. Chen[2]

Summary

Using 34 rice cultivars/lines as materials, the principal component analysis was performed to elucidate the relationships between the panicle density parameters and its 10 related characters. Results showed that the first principal component (Z_1) was mainly concerned with the length factor, the primary branch factor and the total number of spikelets per pancile; The second principal component (Z_2) was largely due to the pancile weight, the primary branch factor and the total number of spikelets per panicle; The third principal component (Z_3) was mainly associated with the length of rachis, the number of primary branches, the number of secondary branches and the ratio of the total number of spikelets of secondary branches and the total number of spikelets per panicle; while, the fourth principal component (Z_4) was mainly performed by the pancile length, the number of primary branches and the average number of spikelets per primary branch.

The relationships between the four principal components and panicle density parameters, evaluated by two different methods K (Number of spikelets/Total length of rachis and primary branches in cm) and L (Number of spikelets/10cm panicle length), were established by stepwise regression analysis method, A total eight equations were obtained, respectively. Among them, four for panicle density parameter K and two for panicle density parameter L, their coefficients of multiple determination were very high (>0.84) . Equations, K_2 ($=0.918Z_1-0.215Z_3$, $R^2=0.888$) and L_3 ($=0.808Z_1+0.374Z_2-0.358Z4, R^2=0.920$), estimated by the use of the least principal components, respectively, were selected as the best models for predicting the panicle density rice.

Moreover, from the relationships between panicle density parameters and its related characters, it was found that the higher panicle weight, average number of spikelets of primary branches, secondary branch factor and the total number of spikelets per panicle. the higher their pancile density. While, the panicle length, length of rachis and the sum of the length of primary branches were down lower as their pancile density toward high.

From the scatter diagram for the related characters of panicle density, 34 cultivars/lines, belonging to seven groups, could be classified into four different panicle density types: very low, low, middle and high panicle density type.

Key words : Rice, Panicle density. Related characters, Principal component analysis, Stepwise regression analysis. Correlation analysis.

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1. Contribution No. 1662 from Taiwan Agricultural Institute (TARI) .

2. Research Assistant, Sinor Agronomist and Agronomist, respectively. Chiayi Agricultural Experiment Station, TARI, Chiayi, Taiwan 600, ROC.

中華農業研究（Jour. Agric. Res. China）42(2)：121～132（1993）

玉米生長分化性狀在不同粒型雜種後裔與期作之變異[1]

謝光照[2]　曾富生[3]

摘要：以玉米三個硬粒種及三個馬齒種之全互交F_1及親本爲材料，分別種植於春作及秋裡作探討期作對生長分化性狀之影響。結果摘要如下：

發現品系間，期作間，粒型組合間及粒型組合×期作之交感作用在大部份性狀均達顯著。在春作，馬齒種自交系之出土至雄穗分化日數較短，而硬粒種之雄穗與雌穗分化間隔日數、單株葉面積及青割乾重均較大。在秋裡作，自交系大部份性狀與春作相類似，僅少數性狀有所差異。不同粒型組合間在春作及秋裡作的表現，有明顯的不同，其中以出土至雄穗分化日數、雄穗與雌穗分化間隔日數、葉片分化速率、單株葉面積及青割乾重等項差異最大。

玉米生長分化在春作正値低溫，秋裡作則正値高溫，致生長分化在期作間有極大的差異存在，春作顯然比秋裡作在出土至雄穗分化日數、雄穗分化始期葉片出現數目、生殖生長期葉片出現速率、單株葉面積等較大；而營養生長期葉片出現速率、雄穗與雌穗分化間隔日數、葉片分化速率均較小。

三種粒型組合間性狀的相關有很大的差異存在；且同種粒型組合，在不同期作下性狀間相關性的表現也有程度上的差別。大部份生長分化性狀與青割乾重相關不顯著，顯然不易當作青割乾重選拔之指標。

關鍵詞：硬粒種、馬齒種、粒型、全互交、分化。

作物的產量是一個相當複雜的性狀，受許多遺傳與環境因子影響。Yamaguchi（1974 a, b, c, d）指出玉米產量主要受品種、環境及栽培管理所控制。其中溫度與光週期爲影響玉米植株生長及分化的兩項重要因子，Francis *et al.*（1969, 1970）的報告指出玉米對光週期敏感，呈現短日反應；在長日及低溫下，玉米雄穗分化始期（tassel initiation）及開花期（anthesis）有延遲的現象（Francis *et al.* 1970; Breuer *et al.,* 1976）。Hunter *et al.*（1974, 1977）指出光週期與溫度對雄穗分化始期均有影響，且各基因型的反應並非固定不變，一般達到雄穗分化始期所需的天數，隨著日長的增加，有延長的現象，愈晚熟的品種所受到的影響愈大；而光週期增長時，營養生長期（即發芽至雄穗分化期）同樣也呈增加現象，且在雄穗分化始期時，植株之葉片數及植株乾物重均較大；但在較低溫下由發芽至雄穗分化始期所需的時間愈長，且基因型不同對溫度的反應也有異，然而高溫則可增加葉數。

臺灣中部春作玉米生育初期的氣溫比秋作低，影響到器官分化的速率，導致春作達到雄穗分化始

1. 臺灣省農業試驗所　研究報告第1663號。
2. 本所農藝系助理研究員。臺灣省　臺中縣　霧峰鄉。
3. 國立中興大學農藝系教授。臺灣省　臺中市。

期所需的日數比秋作長（洪等，1984）。而王等（1988）報告指出玉米播種後，生育初期氣溫愈低，植株發育至雄穗分化始期時之株齡愈大。Warrington and Kanemasu（1983a）相信若以標準溫度來計算，達到雄穗分化始期大約爲播種至開花時間的前面1/3時期，一般晚熟種較早熟種達到雄穗分化所需的時期長；同時並指出平均溫度與雄穗分化始期所需日數的關係爲曲線關係，而在11～28°C範圍內則爲直線關係。

Warrington and Kanemasu（1983b）的研究結果顯示，在自然環境下，生長季節溫度的改變，特別是開花前之溫度，低溫對葉片分化速率及葉片出現速率都具有顯著的影響；在15～28°C間葉片分化速率與葉片出現速率，隨溫度的增加呈近乎直線關係，而其葉片分化與葉片出現速率，品種間沒有顯著差異存在，其值爲0.4～0.44（levaes/day）。而Aitken（1980)指出由雄穗分化至最後一片葉出現之生殖生長期葉片出現速率比從萌芽至雄穗分化始期之營養生長期之葉片出現速率爲快。一般葉片出現速率隨著溫度的增加而增加（Thiagarajah and Hunt, 1982）。王等（1988）之研究指出，在田間與生長箱高溫狀況下，玉米植株在雄穗分化始期以前之出葉速率多高於分化始期以後之出葉速率，顯示營養生長期與生殖生長，有不同的生育特性，對環境因子的反應也具有程度上的差異，並認爲臺中地區栽培玉米之生長受溫度影響較光期爲大。而玉米葉片出現速率隨基因型及發育時期的不同而有差異（Tollenaar *et al.,*（1979, 1984）。

玉米葉片數的多少，主要決定於播種至雄穗分化始期長短及頂端分生組織產生葉之速率，這兩個過程極易受溫度及光週期所影響，葉數對溫度的反應爲非直線；而葉數隨日長增加而增加，每增加一小時日照時間，葉數平均增加0.71片；基因型不同，其葉數也有所差異，愈晚熟品種在長日處理下的葉數愈多（Warrington and Kanemasu, 1983c），但此種現象又隨溫度之升高而漸不明顯（Russell and Stuber, 1983）。Tollenaar and Hunter(1983)的報告指出環境因子對葉片分化速率具有影響，玉米在4～7株齡期，延長光週期及升高溫度對光週期敏感之短日照植株均可增加葉數，且兩者具有加成作用；一般玉米由營養生長期轉爲生殖生長期，發生在總葉數的50%之株齡期。玉米的葉數隨基因型的不同而異，且受溫度及光週期修飾而改變，在較長日照及高溫下具有較多的葉數(Hesketh *et al.,* 1969)。而植株葉面積較大者，產量亦較高，短日處理則具反效果(Hunter, 1980)。

Eik and Hanway（1965）認爲玉米品種間之葉片數、葉片大小有差異存在，一般晚熟種比早熟種具有較大葉面積且葉片出現速率較快；但品種間葉片分化速率之差異則極小。

有關生長與分化性狀之關係，據Hesketh *et al.*（1969）的研究顯示，在溫度變化下，葉數與植株乾重、葉面積等有密切關係。而Arnold（1969）以8個不同基因型爲材料進行研究，發現雄穗分化時之出現葉數與總葉數呈顯著正相關。而Russell and Stuber（1984）則認爲基因型不同，其總葉數與雄穗分化始期出現葉數之相關性並不一致。

本省地處亞熱帶，適合於玉米栽培，玉米在臺灣的生產季節，主要在春作或秋（裡）作，春作播種期一月上旬至三月中旬，秋作則在八月下旬至十月中旬。此兩個期作間之氣象條件差異極大，通常春作由低溫、短日照逐漸轉爲高溫、多濕及較長日照之環境；而秋作則由高溫、長日照與多濕逐漸轉爲低溫，低濕度及較短日照之環境。玉米從種子發芽出土後，即受各種環境因子所影響，又以溫度與光週期爲影響玉米植株生長及分化的兩項重要因子。玉米用於飼料生產者，以硬粒種（flint）及馬齒種（dent）爲主，呂等（1986）的研究顯示馬齒種×馬齒種、馬齒種×硬粒種及硬粒種×硬粒種等三種粒型組合後裔之性狀的表現有差異存在。在不同栽培環境下，三種粒型組合間對環境的反應如何，有關資料尚闕如。本試驗的目的，即在探討臺灣不同期作之環境下，三種粒型組合間之生長分化性狀表現是否有所差異。

材料與方法

本試驗所使用材料，計有下列6個自交系，將其代號、名稱、系譜、起源及粒型，詳列如表1：

Table 1. Inbred lines used for diallel crosse of the experiment.

Code	Inbred	Pedigree	Origin	Kernel form
A	Hi 25	(B14A×MV Source) BC_4	Hawaii, USA	Dent
B	Hi 31	(B68×MV Source) BC_5	Hawaii, USA	Dent
C	Hi 33	(Mo17×MV Source) BC_5	Hawaii, USA	Dent
D	Antigua-2D	Antigua	Caribbean	Flint
E	SW 654	Suwan-1 derivative	Thailand	Flint
F	TA80—2598—44	(TA80—2598×Suwan-1) BC_3	TARI, Taiwan	Flint

以上述6個交系進行全互交組合，共計三十個F_1及六個自交系，於1989年秋裡作（10月7日播種）及1990年春作（2月16日播種）於農業試驗所試驗農場進行試驗。田間試驗採逢機完全區集設計，四重複。小區行長4公尺，播種時行株距80×10cm，3行區，兩粒播，發芽後一週行間拔，每穴留一株，至七葉齡時，開始進行取樣，取樣結束後，行距成為80×20cm。

基肥以臺肥39號複合肥料（N：P_2O_5：K_2O=12：18：12）每公頃施400公斤，於播種前施於播種溝內，澆水後進行播種，再以Atrazine殺草劑進行萌前處理，追肥於植株齊膝期培土時以硫酸銨（21%N）每公頃施375公斤。其他的田間管理工作如一般玉米栽培手册之方法行之。

各種性狀的調查方法如下：

(1)出土至雄穗分化日數（days from seedling emergence to tassel initiation）：由每小區50%以上植株出土日期至雄穗分化始期的日數（天）。

(2)雄穗分化始期葉片出現數目（leaf number at tassel initiation）：依 Warrington and Kanemasu（1983a）方法，由解剖觀察雄穗分化達2mm時，植株葉輪中顯示葉尖突出的葉片數目，以每小區取樣5株之平均值表示。

(3)營養生長葉片出現速率（leaf appearance rate in the vegetative stage）：由幼苗出土至雄穗分化始期之營養生長階段內，以看到葉尖之葉片數目為準之葉片出現速率（雄穗分化始期葉片出現數目／出土至雄穗分化日數）。

(4)雄穗與雌穗分化間隔日數（days from tassel initiation to ear initiation）：解剖觀察雄穗分化始期與雌穗分化始期之間隔日數，以每小區取樣5株之平均值表示。

(5)生殖生長期葉片出現速率（leaf appearance rate in the reproductive stage）：由雄穗分化始期至劍葉抽出期間之葉片出現速率（片／天），以每小區取樣5株之平均值表示。

(6)葉片分化速率（leaf-initiation rate）：植株之總葉片數／出土至雄穗分化始期日數。

(7)總葉片數（total leaf number）：雄穗抽出後，每小區調查5株之平均總葉片數。

(8)單株葉面積（leaf area per plant）：於吐絲後，每小區逢機5株，由頂端往下數第八片葉的長度與最寬度的面積，再乘以0.75及9.39所獲之cm^2數值之平均值（Pearce *et al.*, 1975）。

(9)青割乾種（dry weight at dough stage）：每小區逢機取5株，分別於春作（吐絲後28天）與裡作（吐絲後50天）青割適期進行取樣，然後置於65°C烘乾機內烘七天，再秤其重量，以 g 表示。

試驗所獲之數據，先進行變方分析及平均值差異顯著性比較，及外表型相關係數之估算。

試驗進行期間（1989年10月至1990年5月）之氣象資料，包括月平均氣溫、月總日照時數及日長變化情形示如圖1（中央氣象局，1989—1990）。秋裡作月平均氣溫由25.6°C漸漸下降至16°C，呈下降趨勢；春作月平均氣溫則呈現由低溫漸漸昇高的趨勢。秋裡作的每月日照時數比春作高；秋裡作日照長度由11小時45分鐘降至12月10小時45分鐘，再降至2月的11小時20分鐘；春作日照長度則由11小時20分鐘漸漸增加至13小時45分鐘。顯示春作與秋裡作日長之變化呈相反趨勢。

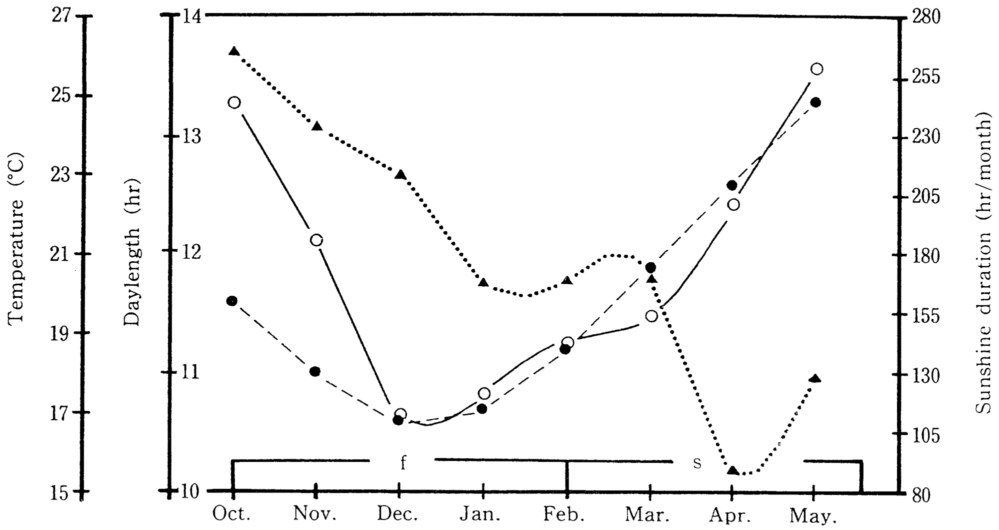

Fig. 1. Monthly mean temperature (○), sunshine duration per month (▲), and daylength (●) at Wufeng (Taichung) area from October, 1989 to May, 1990. "f" and "s" indicate fall and spring crops, respectively.

綜合而言，春作氣溫由低溫漸昇高，日長漸增加，但總日照時數則較少；秋裡作氣溫由高溫漸漸下降，日長呈減少現象，但總日照時數則較春作多。

結果與討論

玉米在臺灣的生長季節，主要在春作及秋（裡）作，由於春作由低溫、短日照逐漸轉爲高溫、多濕及較長日照，而秋作則由高溫、長日照、多濕逐漸轉爲低溫、低濕度及較短日照，因此產量及生長特性有顯著差異（洪等，1984）。一般溫度及光週期爲影響玉米植株生長及分化的兩項重要因子，春作玉米營養生長期間正值低溫與短日照；秋作玉米營養期則逢高溫、長日照。在此種不同期作的環境下（圖1），探討不同粒型組合之玉米的生長分化之反應在育種上是一很重要的問題。本試驗依子粒型將親本自交系分爲馬齒種及硬粒種兩組，而30個 F_1 雜種，依硬粒種及馬齒種兩種子粒型之各種組合方式，區分爲(1)馬齒種同粒型，(2)硬粒種同粒型，(3)馬齒種×硬粒種異粒型等三類進行比較。試驗結果發現，品系間、粒型組合間、期作間及粒型組合×期作間之交感作用，在大部份性狀均呈極顯著差異（Table 2），顯示玉米生長分化性狀會因基因型及栽培環境之不同而形成差異，與Russell and Stuber (1984) 與Kang and Gorman (1989) 之試驗結果類似。

Table 2. Mean squares from combined ANOVA for growth and differentiation characters of maize grown in the spring and fall crop seasons.

Source	df	Days from S. E. to T. I.	Leaf number at T. I.	LAR in the V. S.	Days from T. I. to E. I.	LAR in the R. S.	L. I. rate	TLN	Leaf area per plant	Dry weight at dough stage
Season (S)	1	8,050.7**	25.32**	1.622**	273.19**	0.1573**	3.5754**	56.18**	25,789**	145
Block／seasons	6	0.5**	0.17**	0.003	0.13	0.0002	0.0011**	0.04	242	61
Genotype (G)	35	19.9**	1.02**	0.006**	6.12**	0.0025**	0.0157**	2.19**	3,869**	3,023**
Combination (C)	(2)	87.4**	0.11	0.006	7.77**	0.1155**	0.0459**	4.98**	28,892**	30,599**
Within Dent×Dent	(8)	27.0**	0.71**	0.005**	11.84**	0.0019**	0.0274**	3.29*	4,445**	1,682**
Within Dent×Flint	(17)	11.2**	1.22**	0.001**	3.74**	0.0034**	0.0047**	1.78*	907**	359**
Within Flint×Flint	(8)	14.5**	1.15**	0.015	5.04**	0.0012**	0.0199**	1.26**	3,330**	3,132**
S×G	35	5.7**	0.58**	0.004	5.45**	0.0020**	0.0065**	2.11**	543**	273**
S×C	(2)	4.9**	0.12	0.000	9.74**	0.0005	0.0509**	1.07	1,232**	341*
Within S×D×D	(8)	8.6**	0.31**	0.002**	3.58**	0.0024**	0.0118**	2.00	510**	409**
Within S×D×F	(17)	4.9**	0.51**	0.000**	3.89**	0.0020**	0.0056**	2.51**	188**	144
Within S×F×F	(8)	4.6**	1.13**	0.013	9.53**	0.0017**	0.0039**	1.62**	1,159**	396**
Error	210	0.1	0.07	0.004	0.17	0.0003	0.0003	0.96	77	78

*,**Significant at 5% and 1% levels, respectively.

S. E. : seedling emergence　LAR : leaf appearance rate　L. I. : leaf initiation
T. I. : tassel initiation　E. I. : ear initiation　TLN : total leaf number
V. S. : vegetative stage　R. S. : reproductive stage

在春作環境下，自交系馬齒種較硬粒種具有較少的出土至雄穗分化日數，而雄穗與雌穗分化間隔日數、單株葉面積、青割乾重均以硬粒種較大。不同粒型組合間之表現，顯示硬粒種同粒型組合，其出土至雄穗分化日數、總葉片數及青割乾重等性狀之值較大；異粒型組合，其出土至雄穗分化日數及雄穗分化始期葉片出現數目均較少，而其雄穗與雌穗分化間隔日數、葉片分化速率、總葉片數等均較大；馬齒種同粒型組合，其出土至雄穗分化日數、雄穗分化始期葉片出現數目、營養生長期葉片出現速率、雄穗與雌穗分化間隔日數、生殖生長期葉片出現速率等性狀介於異粒型與硬粒種同粒型之間，而其葉片分化速率、總葉片數、單株葉面積與青割乾重等性狀均較少（Table 3）。

在秋作環境下，自交系馬齒種比硬粒種具有出土至雄穗分化日數較短、雄穗與雌穗分化間隔日數較長，總葉片數、單株葉面積及青割乾重較小的趨勢。至於不同粒型組合之表現，顯示馬齒種同粒型組合較硬粒種同粒型組合，在出土至雄穗分化所需日數及雄穗與雌穗分化間隔日數均較長，葉片分化速率較慢、總葉片數較少、單株葉面積及青割乾重均較小的現象；異粒型組合，除單株葉面積、青割乾重與硬粒種型相近似外，其餘性狀均界於兩同粒型之間（Table 4），與 Eik and Hanway（1965）認爲葉片數、葉片大小及 Tollenaar *et al.*（1984）認爲葉片出現速率隨品種基因型而異之結果類似。

Table 3. Means of the growth and differentiation characters of maize grown in the spring crop season.

Hybrid and inbred	Days from S. E. to T. I.	Leaf number at T. I. (leaves)	LAR in the V. S. (leaves/day)	Days from T. I. to E. I.	LAR in the R. S. (leaves/day)	L. I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5 plant)
				Dent×Dent					
A×B	33.9	11.8	0.34	2.9	0.25	0.57	19.5	4,509	475
A×C	31.8	11.0	0.35	5.6	0.26	0.57	17.7	6,150	823
B×C	31.8	11.4	0.36	5.0	0.28	0.61	19.7	5,907	907
B×A	35.1	11.6	0.33	2.5	0.27	0.54	19.3	4,703	733
C×A	31.4	11.1	0.35	4.7	0.26	0.55	17.5	5,598	750
C×B	32.9	11.8	0.36	4.2	0.25	0.58	19.1	6,152	900
x̄	32.8	11.4	0.35	4.1	0.26	0.57	18.8	5,503	765
				Flint×Flint					
D×E	34.2	11.1	0.32	5.4	0.26	0.55	19.0	6,302	1,017
D×F	33.9	12.2	0.35	3.4	0.24	0.56	19.3	5,702	934
E×F	32.0	11.2	0.35	5.4	0.26	0.61	19.7	5,772	909
E×D	34.0	11.9	0.35	3.5	0.27	0.58	19.9	5,767	1,117
F×D	34.0	11.8	0.34	3.3	0.27	0.58	19.9	5,403	922
F×E	31.8	11.3	0.35	3.5	0.28	0.63	20.2	5,872	1,108
x̄	33.3	11.5	0.34	4.1	0.27	0.59	19.6	5,798	1,001
				Dent×Flint					
A×D	31.9	11.2	0.35	4.7	0.26	0.59	19.0	6,048	935
A×E	31.8	11.2	0.35	4.5	0.26	0.59	19.0	6,367	938
A×F	31.7	11.4	0.36	4.8	0.29	0.62	19.9	5,830	991
B×D	32.0	11.9	0.37	4.7	0.27	0.63	20.3	6,118	1,055
B×E	32.5	12.1	0.37	3.8	0.52	0.61	19.9	6,237	1,123
B×F	32.0	11.9	0.36	4.4	0.28	0.63	20.4	5,648	1,042
C×D	30.7	11.0	0.35	5.5	0.24	0.55	17.1	6,530	1,057
C×E	30.4	10.9	0.35	4.0	0.22	0.58	17.7	6,753	977
C×F	30.4	10.8	0.35	4.5	0.26	0.56	17.2	6,034	763
D×A	32.0	11.4	0.35	4.5	0.26	0.61	19.6	6,297	1,052
D×B	32.1	11.7	0.36	6.9	0.24	0.60	19.5	5,962	1,050
D×C	31.9	11.2	0.35	5.2	0.28	0.62	19.9	6,476	1,003
E×A	31.4	11.1	0.35	4.6	0.27	0.61	19.2	6,348	1,077
E×B	34.9	11.8	0.33	2.0	0.28	0.57	20.0	5,944	1,141
E×C	29.4	10.9	0.37	4.6	0.20	0.59	17.4	6,324	1,053
F×A	33.3	11.8	0.35	3.5	0.27	0.58	19.4	5,789	938
F×B	34.8	12.0	0.34	3.9	0.31	0.59	20.7	5,626	1,036
F×C	30.7	10.7	0.35	4.2	0.28	0.57	17.7	5,542	945
x̄	31.9	11.4	0.35	4.4	0.26	0.59	19.1	6,104	1,010
				Dent					
A	34.0	11.3	0.33	2.4	0.26	0.55	18.7	4,067	391
B	37.0	11.7	0.31	4.2	0.25	0.52	19.5	3,646	611
C	31.1	10.5	0.33	3.7	0.19	0.51	15.9	5,284	464
x̄	34.0	11.2	0.33	3.4	0.23	0.53	18.0	4,332	489
				Flint					
D	34.1	11.0	0.32	4.8	0.23	0.53	18.1	5,116	753
E	35.0	10.6	0.30	4.7	0.24	0.51	18.1	5,353	765
F	35.0	12.4	0.35	4.9	0.24	0.55	19.5	3,659	673
x̄	34.7	11.3	0.32	4.8	0.24	0.53	18.6	4,709	740
L. S. D. 5%	0.4	0.3	0.01	0.5	0.02	0.01	0.5	348	110
L. S. D. 1%	0.5	0.4	0.02	0.7	0.03	0.02	0.7	462	146

S. E. : seedling emergence
T. I. : tassel initiation
V. S. : vegetative stage
LAR : leaf appearance rate
E. I. : ear initiation
R. S. : reproductive stage
L. I. : leaf initiation
TLN : total leaf number

Table 4. Means of growth and differentiation characters of maize grown in the fall crop season.

Hybrid and inbred	Days from S. E. to T. I.	Leaf number at T. I. (leaves)	LAR in the V. S. (leaves/day)	Days from T. I. to E. I.	LAR in the R. S. (leaves/day)	L. I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5 plant)
				Dent×Dent					
A×B	23.5	11.0	0.47	4.8	0.17	0.72	17.0	3,371	569
A×C	18.7	10.5	0.56	8.7	0.22	0.93	17.4	4,642	554
B×C	20.5	10.9	0.53	7.2	0.22	0.89	18.3	4,654	780
B×A	20.7	10.7	0.51	7.5	0.20	0.85	17.7	4,023	606
C×A	20.9	10.6	0.51	7.4	0.22	0.82	17.2	5,114	812
C×B	20.2	10.6	0.52	6.9	0.22	0.83	16.9	5,007	763
x̄	20.7	10.7	0.52	7.1	0.21	0.84	17.4	4,464	681
				Flint×Flint					
D×E	24.9	10.8	0.68	4.9	0.20	0.72	18.0	5,780	1,093
D×F	21.0	11.0	0.52	7.6	0.21	0.87	18.3	5,430	1,124
E×F	22.0	11.0	0.49	6.5	0.21	0.83	18.7	5,283	1,105
E×D	22.0	10.2	0.46	7.0	0.20	0.81	17.9	5,947	1,077
F×D	23.0	11.4	0.49	6.5	0.23	0.80	18.6	4,984	1,098
F×E	22.0	10.9	0.49	7.0	0.22	0.84	18.5	5,325	1,324
x̄	22.4	10.9	0.52	6.6	0.21	0.81	18.3	5,458	1,137
				Dent×Flint					
A×D	20.7	10.2	0.49	7.4	0.20	0.82	17.0	5,043	977
A×E	20.2	10.5	0.52	7.6	0.22	0.89	18.0	5,530	877
A×F	20.7	10.8	0.52	7.2	0.18	0.81	16.9	5,129	1,066
B×D	21.2	11.1	0.52	6.8	0.19	0.84	17.7	5,442	1,021
B×E	21.6	10.5	0.48	6.9	0.22	0.85	18.4	5,677	1,024
B×F	20.6	11.2	0.54	7.1	0.16	0.80	16.5	5,172	1,096
C×D	20.1	10.6	0.52	7.6	0.20	0.84	17.1	5,462	1,062
C×E	21.0	10.4	0.49	7.8	0.22	0.82	17.3	6,129	1,113
C×F	20.7	10.7	0.51	6.9	0.23	0.87	18.0	4,887	901
D×A	21.0	10.7	0.50	7.1	0.24	0.87	18.4	5,363	1,071
D×B	25.0	11.4	0.45	5.0	0.20	0.70	17.7	5,358	1,023
D×C	21.0	10.4	0.49	6.8	0.23	0.85	18.0	5,843	1,019
E×A	21.0	10.5	0.50	6.3	0.21	0.81	17.0	5,897	906
E×B	20.9	10.6	0.50	6.4	0.20	0.85	17.9	5,839	1,124
E×C	21.4	10.8	0.50	6.9	0.18	0.80	17.2	6,173	960
F×A	22.5	11.4	0.50	9.2	0.24	0.79	17.9	5,531	1,053
F×B	25.1	12.1	0.48	3.8	0.26	0.76	19.1	4,788	1,013
F×C	22.6	11.4	0.50	6.0	0.25	0.80	18.1	5,244	1,037
x̄	21.5	10.8	0.50	6.6	0.21	0.82	17.7	5,472	1,019
				Dent					
A	23.2	10.6	0.45	4.6	0.19	0.68	15.8	3,648	456
B	25.0	11.3	0.45	4.8	0.19	0.73	18.4	3,741	685
C	24.3	10.7	0.44	4.3	0.22	0.67	16.4	4,438	616
x̄	24.1	10.8	0.45	4.6	0.20	0.69	16.8	3,942	586
				Flint					
D	26.0	11.2	0.43	3.1	0.26	0.71	18.4	3,368	611
E	26.0	10.2	0.39	3.2	0.19	0.68	17.8	5,244	745
F	24.0	10.4	0.43	4.8	0.21	0.71	17.2	4,814	610
x̄	25.3	10.6	0.42	3.7	0.22	0.70	17.8	4,475	655
L. S. D. 5%	0.5	0.3	0.08	0.6	0.02	0.02	0.5	427	136
L. S. D. 1%	0.6	0.5	0.15	0.8	0.03	0.03	0.6	566	180

S. E. : seedling emergerce　LAR : leaf appearance rate　L. I. : leaf initiation
T. I. : tassel initiation　E. I. : ear initiation　TLN : total leaf number
V. S. : vegetative stage　R. S. : reproductive stage

大部份性狀均呈現期作與粒型組合間之交感作用，隨著各性狀的不同，自交系粒型及粒型組合間在春作及秋裡作的表現有明顯的不同存在 (Tables 2、3及4)。雜交種的表現情形就有很大的差異存在，例如出土至雄穗分化日數：春作爲硬粒種同粒型＞馬齒種同粒型＞異粒型；秋裡作爲硬粒種同

粒型＞異粒型＞馬齒種同粒型。雄穗與雌穗分化間隔日數：春作三種粒型組合間並沒有太大的差異存在；秋裡作則呈現馬齒種同粒型＞硬粒種同粒型與異粒型。葉片分化速率：春作異粒型與硬粒種同粒型明顯的大於馬齒種同粒型；而秋裡作爲馬齒種同粒型＞異粒型＞硬粒種同粒型。單株葉面積：春作爲異粒型＞硬粒型同粒型＞馬齒種同粒型；秋裡作下，異粒型組合與硬粒種同粒型間並沒有明顯差異存在，但兩者均大於馬齒種同粒型。由各性狀的綜合表現，導致春作在吐絲後28天之整株乾重爲異粒型與硬粒種間沒有明顯差異，但均較馬齒種同粒型爲大；秋裡作在吐絲後50天時之整株乾重爲硬粒種同粒型＞異粒型＞馬齒種同粒型。由上述可看出硬粒種與馬齒種間之雜交玉米在臺灣不同期作下各有不同的生育特性及環境適應性（Hasllauer and Malithano, 1976）。

春作的氣溫由低溫逐漸升高，同時日照的長度由11小時20分鐘漸漸增長爲13小時45分鐘；秋裡作，氣溫則由高溫漸漸下降，日長呈現縮短現象，玉米生長分化在春作正值低溫，秋作則正值高溫致生長分化上有極大的差異存在。春作顯然比秋裡作在出土至雄穗分化日數較長，雄穗分化始期葉片出現數目較多，營養生長期葉片出現速率較慢，雄穗與雌穗分化間隔日數較短，生殖生長期葉片出現速率較快，葉片分化速率較小，單株葉面積較大（Table 4），與王等（1988）指出播種後生育初期氣溫越低，植株發育至雄穗分化始期時之株齡較大（即葉片數較多），及洪等（1984）認爲春作玉米生育初期的氣溫比秋作低，影響到器官分化的速率，導致春作達到雄穗分化始期所需之日數比秋作長之結果類似，因而推論在臺中地區玉米之生長受溫度的影響較光期爲大。而Breuer *et al.*（1976），Francis *et al.*（1970），Hunter *et al.*（1974, 1977）等均指出光週期與溫度均會影響玉米的生長分化，更可顯示本試驗之春作及秋裡作，玉米植株生長分化及整乾株重均有極大差異的可能原因。

有關生長分化性狀間之相關，據Hesketh *et al.*（1969）的研究顯示，在變溫度環境下，葉片數目與植株乾重、葉面積有密切關係；而Arnold（1969）發現雄穗分化時出現葉片數與總葉片數呈顯著正相關。但有報告且指出，基因型不同，其總葉片數與雄穗分化始期出現葉片數間之相關性並不完全一樣（Russell and Stuber, 1984），然而Hebert（1990）則認爲玉米早期葉片出現速率與總乾物重有密切相關，可當作選拔指標。本試驗相關分析顯示三種粒型組合間，性狀的相關性有很大的差異；在同粒型組合，在不同期作下，性狀間相關性之表現也有程度上的差別存在（Tables 5，6及7）。在馬齒種同粒型內，不同期作下，相關係數呈現相同反應趨勢且達顯著的性狀有出土至雄穗分化日數與營養生長期葉片出現速率，營養生長期葉片出現速率與葉片分化速率，單株葉面積與青割乾重等；不論春作或秋裡作環境下，單株葉面積的大小可當作青割乾重選拔的指標。在異粒型組合內之雄穗分化始期葉片出現數目及總葉片數，在春作可當作青割乾重選拔之指標，而秋作環境下，生長分化性狀則不適合當作青割乾重選拔之指標。硬粒種同粒型內，在春作環境下，生殖生長期葉片出現速率、單株葉面積與青割乾重達顯著相關；而秋裡作環境下，僅出土至雄穗分化日數、雄穗與雌穗分化間隔日數及葉片分化速率與青割乾重達顯著正相關，可當秋裡作青割乾重之選拔指標。

Table 5. Means of growth and differentiation characters across all maize genotype in the spring and fall crop season.

Crop Season	Days from S. E. to T. I.	Leaf number at T. I. (leaves)	LAR in the V. S. (leaves/day)	Days from T. I. to E. I.	LAR in the R. S. (leaves/day)	L. I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5 plant)
Spring	32.6^a	11.4^a	0.35^b	4.3^b	0.26^a	0.58^b	18.8^a	$5,690^a$	902^a
Fall	22.1^b	10.8^b	0.50^a	6.3^a	0.21^b	0.80^a	17.9^b	$5,091^b$	916^a

Means with the same letter within each colume are not significantly different at LSD 0.01.
S. E. : seedling emergence LAR : leaf appearance rate L. I. : leaf initiation
T. I. : tassel initiation E. I. : ear initiation TLN : total leaf number
V. S. : vegetative stage R. S. : reproductive stage

Table 6. Correlation coefficients among growth and differentiation characters of maize with dent×dent kernel type in the spring and fall crop seasons.

Character	Crop season	Days from S. E. to T. I.	Leaf number at T. I.	LAR in the V. S.	Days from T. I. to E. I.	LAR in the R. S.	L. I. rate	TLN	Leaf area per plant
Leaf number at T. I.	S	0.69**							
	F	0.64**							
LAR in the V. S.	S	−0.78*	−0.09						
	F	−0.97**	−0.47						
Days from T. I. to E. I.	S	−0.54	−0.29	0.53					
	F	−0.95**	−0.49	0.96**					
LAR in the R. S.	S	0.14	0.57	0.30	0.15				
	F	−0.56	−0.44	0.54	0.56				
L. I. rate	S	−0.30	0.38	0.75*	0.36	0.75*			
	F	−0.91**	−0.31	0.97**	0.96**	0.55			
TLN	S	0.64	0.92**	−0.08	−0.21	0.73*	0.53		
	F	−0.19	0.55	0.37	0.41	0.16*	0.57		
Leaf area per plant	S	−0.82**	−0.30	0.89**	0.66**	0.12	0.54	−0.30	
	F	−0.65	−0.49	0.60	0.63	0.92**	0.58	0.10	
Dry weight at dough stage	S	−0.28	0.19	0.59	0.67*	0.54	0.64	0.25	0.73*
	F	−0.26	0.20	0.32	0.35	0.57	0.41	0.52	0.70*

*,**Significant at 5% and 1% levels, respectively. S : Sprng , F : Fall.
S. E. : seedling emergence LAR : leaf appearance rate L. I. : leaf initiation
T. I. : tassel initiation E. I. : ear initiation TLN : total leaf number
V. S. : vegetative stage R. S. : reproductive stage

Table 7. Correlation coefficients among growth and differentiation characters of miaze with dent×flint kernel type in the spring and fall crop seasons.

Character	Crop season	Days from S. E. to T. I.	Leaf number at T. I.	LAR in the V. S.	Days from T. I. to E. I.	LAR in the R. S.	L. I. rate	TLN	Leaf area per plant
Leaf number at T. I.	S	0.78**							
	F	0.80**							
LAR in the V. S.	S	−0.50*	0.12						
	F	−0.72**	−0.17						
Days from T. I. to E. I.	S	−0.47*	−0.24	0.42					
	F	−0.91**	−0.82**	0.56*					
LAR in the R. S.	S	0.67**	0.43	−0.52*	−0.23				
	F	0.40	0.28	−0.35	−0.40				
L. I. rate	S	0.11	0.47	0.44	0.23	0.34			
	F	−0.80**	−0.67**	0.55*	0.69**	0.06			
TLN	S	0.76**	0.85**	−0.06	−0.17	0.68**	0.72**		
	F	0.50*	0.38	−0.41	−0.53*	0.76**	0.09		
Leaf area per plant	S	−0.44	−0.38	0.23	0.20	−0.61**	−0.10	0.37	
	F	−0.27	−0.46	−0.11	0.34	−0.19	0.17	−0.18	
Dry weight at dough stage	S	0.37	0.54*	0.18	−0.12	−0.01	0.32	0.46*	0.11
	F	0.07	0.16	0.07	0.00	−0.09	−0.16	−0.08	0.09

*,**Significant at 5% and 1% levels, respectively. S : Sprng , F : Fall.
S. E. : seedling emergence LAR : leaf appearance rate L. I. : leaf initiation
T. I. : tassel initiation E. I. : ear initiation TLN : total leaf number
V. S. : vegetative stage R. S. : reproductive stage

Table 8. Correlation coefficients among growth and differentiation characters of flint×flint kernel type in the spring and fall crop seasons.

Character	Crop season	Days from S. E. to T. I.	Leaf number at T. I.	LAR in the V. S.	Days from T. I. to E. I.	LAR in the R. S.	L. I. rate	TLN	Leaf area per plant
Leaf number at T. I.	S	0.17							
	F	−0.17							
LAR in the V. S.	S	−0.43	0.80**						
	F	−0.16	0.31						
Days from T. I. to E. I.	S	−0.40	−0.54	−0.25					
	F	−0.97**	0.22	0.31					
LAR in the R. S.	S	−0.62	0.09	0.45	0.05				
	F	0.25	0.75*	−0.12	−0.25				
L. I. rate	S	−0.87**	0.23	0.73*	0.15	0.82**			
	F	−0.95**	0.37	0.19	0.94**	−0.04			
TLN	S	−0.55	0.57	0.85**	−0.12	0.82**	0.89**		
	F	−0.31	0.77**	0.19	0.36	0.50	0.55		
Leaf area per plant	S	−0.49	−0.46	−0.13	0.03	0.49	0.32	0.11	
	F	−0.51	−0.42	0.45	0.59	−0.87**	0.38	−0.13	
Dry weight at dough stage	S	−0.57	−0.02	0.32	−0.07	0.77*	0.65	0.59	0.79**
	F	−0.73*	0.28	0.54	0.82**	−0.25	0.79*	0.56	0.65

*,**Significant at 5% and 1% levels, respectively. S：Sprng，F：Fall.
S. E. : seedling emergence LAR : leaf appearance rate L. I. : leaf initiation
T. I. : tassel initiation E. I. : ear initiation TLN : total leaf number
V. S. : vegetative stage R. S. : reproductive stage

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Effects of Kernel Type and Crop Season on the Variations of Growth and Differentiation Traits in Maize[1]

G. J. Shieh[2] and F. S. Tseng[3]

Summary

Offsprings from a diallel cross including three inbrid lines each of flint and dent maize as parents were grown in the spring and fall crop seasons. Growth and differentiation characters were investigated to compare the differences among genotypes with flint, dent, and flint×dent kernel types. Combined analysis of variance over two crop seasons indicated that the effects of crop season, genotype, kernel type, genotype×season, and kernel type× season were highly significant for nine traits investigated, Day from seedling emergence to tassel initiation, days from tassel initiation to ear initiation, leaf initiation rate, leaf area per plant, and dry weight at dough stage were characteristics showing the most significant difference among kernel ytpes subjected to influences of crop seasons. Significant differences in growth and differentiation traits existed between crop seasons due to the pattern of temperature change during the growth course. Values of days from seedling emergence to tassel initiation, leaf number at tassel initiation, leaf appearance rate in reproductive stage, and leaf area per plant were higher, whereas those of leaf appearance rate in vegetative stage, days from tassel initiation to ear initation, and leaf initiation rate were lower, for spring crop than for fall crop. Correlation coefficients among traits varied for offsprings with different kernel types and between crop seasons. Most growth and differentiation characters were not correlated significantly with whole-plant dry weight at dough stage, and hence were not considered as suitable selection indexes for improvement of silage yield in maize.

Key words : Corn (*Zea mays* L.), Flint, Dent, Kernel type, Diallel, Differentiation.

1. Contribution No. 1663 from Taiwan Agricultural Research Institute.
2. Assistant Agronomist, Department of Agronomy, TARI, Wufeng, Taichung Hsien, Taiwan 413, ROC.
3. Professor, Department of Agronomy, National Chung-Hsing University, Taichung, Taiwan, ROC.

中華農業研究（Jour. Agric. Res. China）42(2)：133～145（1993）

期作對玉米硬粒種與馬齒種組合間生長分化性狀組合力表現之影響[1]

謝光照[2]　曾富生[3]

摘要：以玉米三個硬粒種及三個馬齒種之全互交爲材料，分別種植於春作及秋裡作，探討期作對生長分化等性狀基因表現之影響，其結果摘要如下。

在春作環境下，馬齒種自交系之出土至雄穗分化日數最少，硬粒種之雄穗與雌穗分化間隔日數、單株葉面積及青割乾重均較大；在秋裡作大部份性狀的表現與春作相類似。不同粒型組合間在春作及秋裡作的表現有明顯的不同，其中以出土至雄穗分化日數、雄穗與雌穗分化間隔日數、葉片分化速率、單株葉面積及青割重等項之差異較大。

大部份性狀在兩期作均由累加性（GCA）及非累加性（SCA）基因作用共同控制，且有正反交效應。大部份性狀以累加性變方（GCA/SCA比值）所佔的比例較大，但在不同期作間，且隨性狀的不同，其大小有明顯的變異。

在不同期作下，親本之大部份性狀的一般組合力，馬齒種爲負效應，硬粒種爲正效應。而一般組合力效應值，在春作僅雄穗分化始期葉片出現數目、雄穗與雌穗分化間隔日數等性狀有較大的趨勢，其餘性狀則均以秋裡作較大。

在春作環境下，異粒型組合大部份性狀爲正的特定組合力，而同粒型組合則大多爲負的效應；但在秋裡作環境下，不論是馬齒種同粒型、硬粒種同粒型或異粒型組合，大部份性狀均呈負的特定組合力效應。不同粒型組合間的特定組合力效應易受期作影響。

大部份生長分化性狀之組合力有正反交效應，其效應値的大小，依粒型組合間及期作環境之不同而有差異，但其正反效應變方僅佔總遺傳變方之極小比例。

在春作，大部份性狀以馬齒種同粒型比硬粒種同粒型具有較大之雜種優勢百分比，異粒型組合在營養生長期葉片出現速率、葉片分化速率、單株葉面積及青割乾重等性狀比同粒型組合具有較高的雜種優勢；而其他性狀異粒組合的雜種優勢表現值則介於兩種同粒型組合間。在秋裡作，硬粒種同粒型比馬齒種同粒型具有較大的雜種優勢值，異粒型與同粒型比較，大部份性狀均介於馬齒種同粒型及硬粒種同粒型間。同一粒型組合在不同栽培期作間，其雜種優勢表現也有差異。

關鍵詞：玉米、期作、馬齒種、硬粒種、一般組合力、特殊組合力、正反交效應、雜種優勢。

台灣地處亞熱帶，年平均氣溫在20°C以上，年雨量超過1,500公厘，很適於玉米的生長，而一般學者認爲玉米的產量常因溫度高低、日照長短及雨量分布之多寡而發生變異（Duncan *et al.,* 1973；Hunter，1980），本省春秋二作的氣象迥異，玉米的產量在期作間確有明顯的差異存在（台灣省

1. 台灣省農業試驗所　研究報告第1664號。
2. 本所農藝系助理研究員。台灣省　台中縣　霧峰鄉。
3. 國立中興大學農藝系教授。台灣省　台中市。

政府農林廳，1981），故台灣不同栽培期作下，玉米生長分化可能會有不同，因而影響最終產量表現。探討不同期作下，玉米生長分化性狀之表現，應有助於瞭解影響產量之因子，進而可供選育優良品種之參考。

玉米從種子發芽出土後，即受各種環境因子所影響，其中以溫度及光週期對生長及分化影響較大。Hunter *et al.*（1974，1977）及王（1988）指出光週期與溫度對雄穗分化始期均有影響，洪等（1984）也指出玉米器官分化速率及達到雄穗分化始期日數因期作之不同而有異。Russell and Stuber（1985）發現達到雄穗分化始期所需日數的 GCA（general combining ability），SCA（specific combining ability），GCA x E（environment），SCA x E 均達極顯著，其基因效應極易受環境影響。玉米的葉數隨基因型的不同而異，且受溫度及光週期修飾而改變，在較長日照及較高溫下具有較多的葉數（Hesketh *et al.*,1969；Warrington and Kanemasu, 1983c）。Russell and Stuber（1984）的研究發現，玉米達雄穗分化始期所需日數之 GCA 變方佔0.89，總葉片數的 GCA 變方佔0.98，顯示此等性狀之 SCA 的重要性很小。Russell and Stuber（1983）指出玉米由種植至雄穗分化所需的日數與總葉片數兩者的遺傳行爲，並沒有正反交效應。葉數明顯的受累加性作用所影響（Wu，1987），但 Rood and Major（1981）指出玉米葉數在基因型間有差異存在，葉數主要受非累加性之遺傳變方控制，其中增加葉數的現象爲不完全顯性因子所控制，且無正反效效應。Russell and Stuber（1985）由全互交分析顯示玉米植株總葉數的 GCA、GCA x E、SCA x E 均達極顯著，而 GCA 均方及 GCA x 環境均方遠超過 SCA 均方，顯示總葉片數的 GCA 較 SCA 重要；在總葉片數、雄穗分化始期日數之 GCA x 環境交感的效應中，日長效應爲影響的主因。

Warrington and Kanemasu（1983b）的研究結果顯示，在自然環境下，生長季節溫度的改變，特別是開花前之低溫，對葉片分化速率及葉片出現速率都具有顯著的影響，而品種間沒有顯著差異存在。通常植株葉面積在長日及高溫下較大，短日處理則效果相反（Hunter，1980）。

雜種優勢之表現常因種源間的遺傳歧異性而異（Hallauer and Sears,1972）。Moreno-Gonzalez and Dudley（1981）及 Melchinger *et al.*（1986）的研究均指出以馬齒種與硬粒種之雜交種表現較優。Moreno-Gonzalez（1988）曾在歐洲硬粒種及美國馬齒種間之雜交組合中，得到累加性作用均大於顯性作用，並且特定組合力在異型組合中大都爲正値，在同粒型組合中大多爲負値，認爲在歐洲地區，馬齒種 x 硬粒種爲具有價値之一種雜種優勢模式。

本試驗目的即在探討台灣不同期作條件下，三種粒型組合間（馬齒種 x 馬齒種、馬齒種 x 硬粒種、硬粒種 x 硬粒種）生長分化性狀的遺傳型式是否有異，及其雜種優勢的表現程度是否因粒型及其期作而不同，以便作爲玉米品種選育雜種模式採用之參考。

材料與方法

本試驗所使用材料爲6個自交系進行全互交組合，共得三十個 F_1（馬齒種 x 馬齒種6組合，硬粒種 x 馬齒種18組合，硬粒種 x 硬粒種6組合）及六個自交系，於1989年秋裡作（10月7日播種）及1990年春作（2月16日播種）於農業試驗所試驗農場進行試驗（謝與曾，1993）。田間試驗採逢機完全區集設計，四重複，小區行長4公尺，行株距80 x 10cm，3行區，兩粒播，發芽後一週行間拔，每穴留一株，至七葉齡時開始進行取樣，取樣結束後行株距成爲80 x 20cm。

基肥以台肥39號複合肥料（N：P_2O_5：K_2O＝12：18：12）每公頃施400公斤，於播種前施於播種溝內，澆水後進行播種，再以 Atrazine 殺草劑進行萌前處理。追肥以硫酸銨（21% N），於玉米長至齊膝期時施用，每公頃施375公斤，然後進行培土，其他管理方法如一般玉米栽培管理方法行之

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調查性狀包括出土至雄穗分化日數（days from seedling emergence to tassel initiation）、雄穗分化始期葉片出現數目（leaf number at tassel initiation）、營養生長期葉片出現速率（leaf appearance rate in the vegetative）、雄穗與雌穗分化間隔日數（days from tassel initiation to ear initiation）、生殖生長期葉片出現速率（leaf appearance rate in the reproductive stage）、葉片分化速率（leaf-initiation rate）、總葉數（total leaf number）、單株葉面積（leaf area per plant）、青割乾種（dry weight at dough stage），其調查方法詳述於前篇報告中（謝與曾，1993）。

試驗所獲之數據先進行變方分析及平均値差異顯著性比較，再以 Griffing（1956）方法一，（模式 I），進行組合力分析與雜種優勢之估算。

試驗進行期間（1989年10月至1990年5月）之月平均氣溫的變化，秋裡作由25.6°C漸漸下降至16°C，春作則呈現由低溫漸漸昇高的趨勢。在月總日照時數的變化方面，秋裡作的總日照時數比春作高。日長的變化情形，秋裡作日照長度由11小時45分鐘降至12月的10小時45分鐘，再降至2月的11小時20分鐘；春作日照長度則由11小時20分鐘漸漸增加至13小時45分鐘。綜合而言，春作氣溫由低溫漸昇高，日長漸增加，但總日照時數則較少；秋裡作氣溫由高溫漸漸下降，日長呈漸漸減少現象，但總日照時數則較春作多（謝與曾，1993）。

結果與討論

玉米在台灣有春作及秋作兩個主要的生長季節，但由於春作由低溫及短日照逐漸轉爲高溫、多濕及較長日照之環境，而秋作則由高溫、長日照、多濕逐漸轉爲低溫、低濕度及較短日照，致兩個期作之產量有顯著差異。環境因子中，溫度及光週期爲影響玉米植株生長及分化的兩項重要因子，春作玉米營養生長期正値低溫，短日照，秋作玉米營養期則逢高溫與長日照，在此種截然不同的環境下，爲探討不同粒型組合之玉米的生長分化是否有差異，乃依子粒型將親本自交系分爲馬齒種及硬粒種兩組，而30個 F_1 依組合區分爲(1)馬齒種同粒型，(2)硬粒種同粒型，(3)馬齒種 x 硬粒種異粒型等三組進行比較。根據試驗結果顯示，品系間、粒型組合間、期作間及粒型組合 x 期作間之交感作用，在大部份性狀均呈極顯著差異。在春作環境下，粒型組合間除雄穗分化始期葉片出現數目外，其他性狀均呈現極顯著差異，在秋裡作所調查的性狀除雄穗分化始期葉片出現數目、營養生長期葉片出現速率及生殖生長期葉片出現速率外，其他性狀均呈現極顯著差異（謝與曾，1993）。由上述結果顯示不同粒型組合間，在春作及秋裡作環境下，生長分化性狀有明顯異存在，與 Russell and Stuber（1984）、Kang and Gorman（1989）等之結果相類似。

玉米爲異交作物，評估自交系時，較適合以 Griffing 之方法進行組合力分析，Griffing（1956）之組合力分析法，係將親本組合力分爲一般組合力（GCA）及特定組合力（SCA）二種，一般組合力主要受基因之累加性效應所影響，特定組合力則受基因之顯性效應或非等位基因間之相互作用所影響（Sprague and Tatum, 1942）。而 Rojas and Sprague（1952）曾指出 GCA 與SCA 變方的大小，可用於決定基因的作用形式。本試驗顯示不論在春作或秋裡作環境下，大部份性狀均由累加性（GCA）及非累加性（SCA）基因共同控制，而所調查的性狀，除營養生長期葉片出現速率外，其餘性狀均有正反交效應（Table 1）。由 GCA/SCA 比値比較，可看出在春作及秋裡作環境下，雄穗分化始期葉片出現數目、生殖生長期葉片出現速率、總葉片數、單株葉面積及青割乾重等性狀均大於1，表示累加性的變方所佔的比例較非累加性變方來得大；其餘性狀之 GCA/SCA 比値小於1，顯然

這些性狀以非累加性之變方佔較大比例。總葉片數及達雄穗分化始期所需日數等性狀之作用以累加性部份佔較大比例，與 Russell and Stuber (1984，1985) 等之結果類似；而總葉數及出土至雄穗分化日數有正反交效應，與 Russell and Stuber (1983) 之結果不同，可能爲所使用之材料及栽培環境影響到基因的表現所致。

由春作及秋裡作之 GCA/SCA 比值，知大部份生長分化性狀是由 GCA 及 SCA 共同控制，但不同期作間的 GCA/SCA 比值有明顯的差異。由 Table 1可看出，在春作環境下，出土至雄穗分化日數、雄穗分化始期葉片出現數目、營養生長期葉片出現速率、雄穗與雌穗分化間隔日數、葉片分化速率、總葉數等性狀之 GCA/SCA 比值明顯的大於秋裡作。而生殖生長期葉片分化速率、單株葉面積及青割整株乾重等性狀在春作 GCA/SCA 比值則小於秋裡作，顯示不同環境下，控制這些性狀的基因表現效果受到某種程度的抑制或增強。Russell and Stuber (1985) 也曾報告達到雄穗分化始期所需日數及總葉數之 GCA x E 與 SCA x E 之交感作用達極顯著，認爲基因的表現極易受環境所影響。

Table 1. Mean squares of growth and differentiation characters in maize from combining ability analysis of a 6 x 6 diallel cross grown in the spring and fall crop seasons.

Crop seasons	Source	df	Days from S.E. to T.I.	Leaf number at T.I.	LAR in the V.S.	Days from T.I. to E.I.	LAR in the R.S.	L.I. rate	TLN	Leaf area per plant	Dry weight at dough stage
Spring	G. C. A.	5	9.71**	0.99**	0.0001**	1.135**	0.0012**	0.0005**	5.86**	1,255**	741**
	S. C. A.	15	2.82**	0.15**	0.0003**	1.473**	0.0006**	0.0019**	0.58**	864**	554**
	R. E.	15	0.73**	0.04**	0.0001	0.523**	0.0002**	0.0005**	0.39**	46*	66**
	Error	105	0.02	0.01	0.0000	0.035	0.0001	0.0000	0.04	15	15
	G.C.A./S.C.A.		3.43	6.44	0.46	0.77	1.79	0.30	10.06	1.45	1.33
Fall	G. C. A.	5	4.17**	0.55**	0.0002	1.115**	0.0008**	0.0007**	1.34**	1,424**	1,065**
	S. C. A.	15	4.43**	0.12**	0.0029	2.868**	0.0003**	0.0074**	0.30**	707**	637**
	R. E.	15	2.36**	0.09**	0.0021	1.134**	0.0006**	0.0027**	0.48**	62**	62**
	Error	105	0.03	0.01	0.0018	0.053	0.0001	0.0001	0.03	23	23
	G.C.A./S.C.A.		0.94	4.30	0.07	0.38	2.51	0.09	4.38	2.01	1.67

*,**Significant at 5% and 1% levels, respectively.
S.E. : seedling emergence; LAR : leaf appearance rate; L.I. : leaf initiation
T.I. : tassel initiation; E.I. : ear initiation; TLN : total leaf number
V.S. : vegetative stage; R.S. : reproductive stage

分析不同期作下不同粒型親本自交系的一般組合力列於表2，在春作環境下，馬齒種除營養生長期葉片出現速率爲正效應外，其餘性狀爲負效應；而硬粒種的表現大致與馬齒種呈相反趨勢。在秋裡作，馬齒種除營養生長期葉片出現速率、雄穗與雌穗分化間隔日數、葉片分化速率爲正效應，其餘性狀均爲負效應；而硬粒種之表現則爲相反現象。期作間一般組合力效應值之比較，大部份性狀都有明顯的差異存在，調查的性狀中，除雄穗分化始期葉片出現數目、雄穗與雌種分化間隔日數等性狀春作有較大的趨勢外，其餘性狀均以秋裡作有較大的一般組合力效應。

Table 2. Estimates of general combining ability effects for growth and differentiation characters of six maize parental inbreds in a diallel-cross analysis grown in the spring and fall crop seasons.

Crop seasons	Kernel form	Parental inbreds	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5-plant)
		A	−0.05	−0.047	−0.0009	−0.42	0.006	−0.001	−0.06	−208	−110
	Dent	B	1.16	0.373	−0.0008	−0.30	0.007	0.004	0.77	−348	− 11
		C	−1.60	−0.413	0.0045	0.22	−0.015	−0.011	−1.27	312	− 59
		x̄	−0.16	−0.029	0.0009	−0.16	−0.000	−0.003	−0.19	−81	− 60
Spring		D	0.24	0.031	−0.0016	0.38	−0.002	−0.000	0.12	213	74
	Flint	E	0.03	−0.193	−0.0057	0.06	−0.006	0.000	0.00	342	97
		F	0.21	0.248	0.0044	0.04	0.010	0.009	0.43	−311	9
		x̄	0.16	0.029	−0.0009	0.16	0.000	0.003	0.19	81	60
	S.E.	(gi-gj)	0.06	0.054	0.0009	0.07	0.003	0.003	0.08	50	16
		A	−0.72	−0.150	0.0026	0.32	−0.005	0.003	−0.51	−349	−132
	Dent	B	0.34	0.241	−0.0035	−0.29	−0.010	−0.005	0.14	−356	− 50
		C	−0.77	−0.120	0.0051	0.43	0.009	0.014	−0.33	75	− 63
		x̄	−0.38	−0.009	0.0014	0.15	−0.001	0.004	−0.23	−210	− 81
Fall		D	0.56	0.037	0.0039	−0.21	0.006	−0.005	0.27	24	66
	Flint	E	0.32	−0.262	−0.0052	−0.15	−0.006	−0.003	0.20	580	91
		F	0.27	0.254	−0.0030	−0.10	0.005	−0.003	0.22	25	87
		x̄	0.38	0.009	−0.0014	−0.15	0.001	−0.004	0.23	210	81
	S.E.	(gi-gj)	0.07	0.055	0.0170	0.09	0.003	0.003	0.07	62	19

S.E.: seedling emergence
T.I.: tassel initiation
V.S.: vegetative stage
LAR: leaf appearance rate
E.I.: ear initiation
R.S.: reproductive stage
L.I.: leaf initiation
TLN: total leaf number

Moreno-Gonzalea (1988) 曾在歐洲硬粒種及美國馬齒種之雜交組合中，得知基因的累加性作用大於顯性作用，並指出在異粒型組合中之特定組合力大多爲正値，在同粒型組合中大多爲負値。而本研究在春、秋作之試驗結果發現所調查生長分化性狀亦有類似情形，異粒型組合大部份呈現正的特定組合力效應；同粒型則大多爲負的效應(Table 3)。秋裡作環境下，不論是馬齒種同粒型或硬粒種同粒型組合，大部份的性狀均呈現負的特定組合力效應；而異粒型組合中，除出土至雄穗分化日數、生殖生長期葉片出現速率及總葉數爲負値外，其餘六性狀爲正値(Table 4)。比較期作間不同粒型組合之特定組合力效應，發現大部份性狀在春作及秋裡作之反應趨勢相類似，但雄穗分化始期葉片出現數目、生殖生長期葉片出現速率、總葉片數等性狀，即使爲同種粒型組合，也因期作環境的不同而反應趨勢有明顯的差異(Tables 3，4)，顯示不同粒型組合間的特定組合力效應也易受環境影響。

Table 3. Estimates of specific combining ability effects for growth and differentiation characters of maize in a 6 x 6 diallel-cross analysis grown in the spring crop season.

Combination	Genotype	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5-plant)
	A x A	1.42	0.005	−0.014	−1.08	−0.013	−0.030	−0.20	−1,204	−289
	A x B	0.73	−0.015	−0.008	−0.95	−0.011	−0.024	−0.34	−526	−175
Dent	A x C	0.10	0.097	0.001	1.01	0.012	−0.004	−0.09	79	55
x	B x B	1.99	−0.436	−0.031	0.47	−0.025	−0.063	−1.14	−1,347	−268
Dent	B x C	0.11	0.251	0.006	0.29	0.018	0.025	0.88	375	72
	C x C	1.63	−0.061	−0.020	−1.08	−0.038	−0.047	−0.53	−1,031	−319
	x̄	1.00	−0.026	−0.011	−0.22	−0.009	−0.024	−0.22	−609	−154
	D x D	0.96	−0.502	−0.024	−0.26	−0.022	−0.050	−1.14	−1,000	−266
	D x E	1.14	0.222	−0.005	−0.34	0.016	−0.011	0.32	−211	6
Flint	D x F	0.83	0.305	0.000	−1.43	−0.008	−0.015	−0.00	−38	−56
x	E x E	2.24	−0.427	−0.035	0.25	−0.016	−0.067	−0.95	−1,022	−331
Flint	E x F	−1.03	−0.244	0.003	1.08	0.008	0.032	0.46	101	−0
	F x F	1.88	0.538	−0.002	0.42	−0.037	−0.043	−0.35	−1,406	−247
	x̄	1.00	−0.018	−0.010	−0.04	−0.009	−0.025	−0.27	−596	−149
	A x D	−0.91	−0.073	0.007	0.26	0.000	0.022	0.20	478	128
	A x E	−1.03	−0.023	0.009	0.58	0.007	0.023	0.16	553	118
	A x F	−0.31	0.009	0.004	0.17	0.004	0.014	0.26	640	163
	B x D	−2.03	−0.044	0.020	1.36	−0.006	0.034	−0.01	485	88
Dent	B x E	−0.15	0.355	0.011	−1.32	0.003	0.005	0.17	406	144
x	B x F	−0.65	−0.111	0.001	0.05	0.021	0.021	0.34	607	138
Flint	C x D	0.01	0.093	0.002	0.41	0.020	0.019	0.63	287	113
	C x E	−1.15	0.118	0.016	−0.34	−0.025	0.016	−0.17	192	75
	C x F	−0.71	−0.498	−0.006	−0.30	0.012	−0.009	−0.72	96	2
	x̄	−0.77	−0.019	0.007	0.10	0.004	0.016	0.09	416	108
S.E. (Sii-Sjj)		0.17	0.154	0.005	0.21	0.008	0.007	0.24	143	45
S.E. (Sii-Sij)		0.17	0.154	0.005	0.21	0.008	0.007	0.24	143	45
S.E. (Sii-Sjk)		0.15	0.133	0.004	0.18	0.007	0.007	0.20	124	39
S.E. (Sij-Sik)		0.13	0.122	0.004	0.17	0.007	0.006	0.19	113	36
S.E. (Sij-Skl)		0.12	0.109	0.003	0.15	0.006	0.005	0.17	101	32

S.E. : seedling emergence
T.I. : tassel initiation
V.S. : vegetative stage
LAR : leaf appearance rate
E.I. : ear initiation
R.S. : reproductive stage
L.I. : leaf initiation
TLN : total leaf number

Table 4. Estimates of specific combining ability effects for growth and differentiation characters of maize in a 6 x 6 diallel-cross analysis grown in the fall crop season.

Combination	Genotype	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm²)	Dry weight at dough stage (g/5-plant)
	A x A	2.54	0.054	−0.046	−2.32	−0.015	−0.131	−0.88	−745	−195
	A x B	0.42	−0.062	−0.005	−0.15	−0.011	−0.015	0.00	−688	−145
Dent	A x C	−0.77	0.000	0.028	0.96	0.007	0.053	0.45	45	−37
x	B x B	2.21	−0.029	−0.041	−0.89	0.000	−0.058	0.40	−636	−130
Dent	B x C	−1.32	−0.166	0.029	0.62	0.010	0.051	0.10	20	−31
	C x C	3.74	0.145	−0.067	−2.85	−0.007	−0.160	−0.64	−804	−173
	x̄	1.13	−0.009	−0.172	−0.77	−0.002	−0.043	−0.09	−468	−118
	D x D	2.76	0.329	−0.075	−2.74	−0.035	−0.078	0.17	−1,772	−437
	D x E	0.48	−0.070	0.075	0.02	−0.011	−0.027	−0.19	167	10
Flint	D x F	−0.89	0.112	0.012	1.06	−0.003	0.041	0.23	66	41
x	E x E	3.25	−0.120	−0.097	−2.75	−0.003	−0.112	−0.27	−1,009	−354
Flint	E x F	−0.69	0.162	0.002	0.71	0.002	0.036	0.46	393	119
	F x F	1.35	−0.904	−0.059	−1.31	−0.017	−0.080	−0.90	−328	−480
	x̄	1.04	−0.081	−0.023	−0.83	0.001	−0.037	−0.05	−544	−183
	A x D	−1.07	−0.283	−0.006	0.84	0.006	0.046	0.27	436	173
	A x E	−1.10	0.091	0.014	0.48	0.011	0.047	0.14	389	16
	A x F	−0.02	0.200	0.016	0.20	0.001	0.000	0.00	562	188
	B x D	0.01	0.150	−0.008	0.13	−0.015	−0.019	−0.40	641	89
Dent	B x E	−1.49	−0.255	0.006	0.77	0.013	0.058	0.14	442	116
x	B x F	0.15	0.333	0.019	−0.48	0.002	−0.015	−0.25	220	101
Flint	C x D	−1.29	−0.237	0.001	0.67	−0.011	0.037	−0.08	461	121
	C x E	−0.45	0.162	−0.001	0.76	−0.012	−0.001	−0.28	403	91
	C x F	0.10	0.095	0.008	−0.18	0.013	0.018	0.45	−126	28
	x̄	−0.58	0.021	0.005	0.35	−0.001	0.019	−0.00	381	103
S.E. (Sii-Sjj)		0.20	0.157	0.048	0.26	0.010	0.010	0.20	176	56
S.E. (Sii-Sij)		0.20	0.157	0.048	0.26	0.010	0.010	0.20	176	56
S.E. (Sii-Sjk)		0.18	0.136	0.042	0.23	0.008	0.009	0.18	152	48
S.E. (Sij-Sik)		0.16	0.124	0.038	0.21	0.008	0.008	0.16	139	44
S.E. (Sij-Skl)		0.14	0.111	0.034	0.18	0.007	0.007	0.14	124	39

S.E. : seedling emergence　LAR : leaf appearance rate　L.I. : leaf initiation
T.I. : tassel initiation　E.I. : ear initiation　TLN : total leaf number
V.S. : vegetative stage　R.S. : reproductive stage

由組合力分析結果可看出大部份生長分化性狀具有正反交效應（Table 1），經進一步比較其效應值的大小，依粒型組合及期作環境的不同，反應趨勢有差異存在，而正反交效應變方僅佔遺傳變方中之極小比例，此一結果與 Baynes and Brawn（1973）及 Pollmer *et al.*（1979）均認爲玉米的正反交效應變方佔總遺傳變方僅極小比例，且易受栽培環境所影響之結論相同，因此此種效應被認爲並不重要或不具利用價值（Pollmer *et al.*, 1979），在育種過程中可被忽略，對玉米改良影響不大。

Table 5. Estimates of reciprocal effects for growth and differentiation characters of maize in a 6 x 6 diallel-cross analysis grown in the spring crop season.

Combination	Hybrids	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm²)	Dry weight at dough stage (g/5-plant)
Dent	A x B	−0.62	0.100	0.009	0.20	−0.005	0.013	0.10	−96	−128
x	A x C	−0.27	−0.025	0.002	0.45	0.000	0.008	0.10	276	36
Dent	B x C	−0.55	−0.200	−0.000	0.40	0.014	0.018	0.27	−122	3
	x̄	−0.48	−0.041	0.003	0.35	0.003	0.013	0.01	19	−29
Flint	D x E	0.10	−0.400	−0.012	0.92	−0.001	−0.014	−0.45	267	−50
x	D x F	−0.02	0.175	0.005	0.02	−0.016	−0.008	−0.30	149	6
Flint	E x F	0.10	−0.050	−0.002	−0.12	−0.006	−0.009	−0.25	−49	−99
	x̄	0.05	−0.091	−0.003	0.27	−0.008	−0.011	−0.33	122	−47
	A x D	−0.05	−0.100	−0.002	0.10	0.000	−0.008	−0.30	−124	−58
	A x E	0.17	0.025	−0.001	−0.05	−0.001	−0.006	−0.10	9	−69
	A x F	−0.77	−0.200	0.002	0.62	0.011	0.021	0.22	20	26
	B x D	−0.05	0.100	0.003	−1.12	0.013	0.014	0.42	78	2
Dent	B x E	−1.22	0.125	0.016	0.90	−0.014	0.020	−0.05	146	−9
x	B x F	−1.40	−0.050	0.010	0.22	−0.012	0.021	−0.15	11	2
Flint	C x D	−0.57	−0.100	0.003	0.15	−0.021	−0.034	−1.42	27	26
	C x E	0.50	0.000	−0.006	−0.27	0.012	−0.004	0.15	214	−38
	C x F	−0.12	0.025	0.002	0.15	−0.010	−0.006	−0.27	246	−90
	x̄	−0.39	−0.019	0.003	0.07	−0.002	0.001	−0.16	69	−22
S.E. (Rjj)		0.10	0.094	0.003	0.13	0.005	0.004	0.14	88	27
S.E. (Rij-Rkl)		0.15	0.109	0.004	0.18	0.007	0.007	0.20	124	35

S.E.: seedling emergence　LAR: leaf appearance rate　L.I.: leaf initiation
T.I.: tassel initiation　E.I.: ear initiation　TLN: total leaf number
V.S.: vegetative stage　R.S.: reproductive stage

Table 6. Estimates of reciprocal effects for growth and differentiation characters of maize in a 6 x 6 diallel-cross analysis grown in the fall crop season.

Combination	Hybrids	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm²)	Dry weight at dough stage (g/5-plant)
Dent	A x B	1.40	0.17	−0.022	−1.35	−0.012	−0.065	−0.35	−326	−18
x	A x C	−1.07	−0.07	0.026	0.65	0.000	0.053	0.12	−251	−129
Dent	B x C	0.15	0.15	0.003	0.15	0.003	0.029	0.72	−176	8
	x̄	0.15	0.08	0.002	−0.18	−0.003	0.005	0.16	−251	−46
Flint	D x E	1.47	0.30	0.108	−1.02	0.004	−0.046	0.05	−83	7
x	D x F	−1.05	−0.20	0.015	0.52	−0.009	0.032	−0.15	223	12
Flint	E x F	0.00	0.05	−0.003	−0.22	−0.001	−0.004	0.10	−20	−109
	x̄	0.14	0.05	0.040	−0.24	−0.065	−0.006	0.00	39	−29
	A x D	−0.12	−0.25	−0.008	0.12	−0.021	−0.028	−0.70	−160	−46
	A x E	−0.40	−0.02	0.009	0.67	0.005	0.041	0.50	−183	−14
	A x F	−0.92	−0.30	0.008	0.50	−0.029	0.010	−0.52	−201	6
	B x D	−2.02	−0.17	0.036	0.90	−0.006	0.067	−0.02	42	−0
Dent	B x E	0.32	−0.05	−0.009	0.25	0.007	−0.001	0.25	−81	−50
x	B x F	−2.22	−0.47	0.029	1.65	−0.048	0.020	−1.27	192	41
Flint	C x D	−0.45	−0.07	0.014	0.37	−0.015	−0.004	−0.47	−190	21
	C x E	−0.20	−0.17	−0.001	0.42	0.021	0.010	0.05	−21	76
	C x F	−0.95	−0.32	0.007	0.47	−0.008	0.036	−0.05	−178	−68
	x̄	−0.77	−0.20	0.009	0.59	−0.009	0.053	−0.25	−86	−38
S.E. (Rjj)		0.12	0.09	0.029	0.16	0.006	0.006	0.12	107	34
S.E. (Rij-Rkl)		0.18	0.13	0.042	0.23	0.008	0.009	0.18	152	48

S.E.：seedling emergence LAR：leaf appearance rate L.I.：leaf initiation
T.I.：tassel initiation E.I.：ear initiation TLN：total leaf number
V.S.：vegetative stage R.S.：reproductive stage

種源間之遺傳歧異性被認爲是造成雜種優勢表現之主要原因（Hallauer and Sears, 1972），由遺傳距離之研究，發現遺傳歧異性不僅存在於不同種源間或不同地區來源之雜種間，亦可能存在於同粒型或同地區來源之種源內（Moll *et al.*, 1962；Paterniani and Lonnquist, 1963）。而 Moreno-Gonzalez and Dudley（1981），Melchinger *et al.*（1986）及 Moreno-Gonzalez（1988）均認爲馬齒種 x 硬粒種之雜交組合模式表現較佳。本試驗結果發現所調查的生長分化性狀，在春作環境下，除葉片分化速率、總葉片數外，其餘性狀均以馬齒種同粒型較硬粒種同粒型之雜種優勢值大；在異粒型組合方面，營養生長期葉片出現速率、單株葉面積、葉片分化速率及青割乾重等性狀較同粒型

組合有較高的雜種優勢值，其他性狀則介於馬齒種同粒型與硬粒種同粒型組合之間（Table 7）。秋裡作環境下，大部份性狀以硬粒種同粒型較馬齒同粒型之雜種優勢值大；於異粒型與同粒型組合比較，發現除單株葉面積外，其餘性狀之雜種百分比介於馬齒種同粒型及硬粒種同粒型組合間（Table 8）。就青割乾重之雜種優勢表現而言，馬齒種同粒型春作爲57.5，秋裡作則降爲16.3；異粒型組合春作爲43.3，秋裡作爲66.5；硬粒種同粒型春作爲35.1，秋裡作則爲73.6。由上可知春作爲異粒型大於兩種同粒型，秋裡作則爲硬粒種同粒型＞異粒型＞馬齒種同粒型。而同粒型組合，在不同栽培期作下，其雜種優勢表現有差異，可能係期作間溫度的變化而影響玉米植株性狀雜種優勢表現之結果（Rood *et al.*, 1985）。

Table 7. Heterosis percentage for growth and differentiation characters of maize grown in the spring crop season.

Combination	Hybrids	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5-plant)
Dent	A x B	−2.7	1.7	4.5	−19.4	3.1	4.2	1.4	19.4	20.5
x	A x C	−4.3	1.1	5.7	67.7	16.7	6.4	1.5	25.6	83.9
Dent	B x C	−4.9	4.4	9.6	15.0	22.6	15.4	9.4	35.0	68.0
	$\bar{x}$	−4.0	2.4	6.6	21.1	14.1	8.7	4.1	26.7	57.5
Flint	D x E	−1.3	6.3	7.7	−7.0	13.8	9.1	7.5	15.2	37.8
x	D x F	−1.7	2.4	4.2	−30.9	8.6	5.8	3.9	26.5	27.4
Flint	E x F	−8.8	−2.6	6.8	15.5	13.2	16.3	5.9	29.2	40.1
	$\bar{x}$	−3.9	2.0	6.3	−7.4	11.9	10.4	5.8	23.6	35.1
	A x D	−6.2	1.5	8.2	25.6	7.4	11.6	4.7	34.4	69.2
	A x E	−8.3	1.7	10.8	27.7	7.7	13.5	4.0	34.9	74.2
	A x F	−5.7	−2.2	3.8	13.6	11.8	9.2	2.8	50.3	81.1
	B x D	−9.8	3.7	15.1	27.6	7.1	17.2	5.7	37.8	50.9
Dent	B x E	−6.3	7.0	14.5	−35.5	8.8	13.5	6.2	35.3	64.4
x	B x F	−7.2	−1.3	5.4	−8.7	21.1	13.6	5.3	54.3	61.6
Flint	C x D	−3.9	3.4	7.6	25.2	23.5	13.1	8.6	25.0	65.1
	C x E	−9.3	3.4	13.8	1.7	−0.4	14.2	3.3	22.9	65.1
	C x F	−7.4	−6.4	1.3	0.5	22.6	6.7	−1.5	29.4	50.1
	$\bar{x}$	−7.1	1.2	8.9	8.6	12.2	12.5	4.3	36.0	64.6
S.E.		2.7	3.5	4.1	26.5	7.5	4.1	2.9	10.5	18.9

S.E.：seedling emergence　LAR：leaf appearance rate　L.I.：leaf initiation
T.I.：tassel initiation　E.I.：ear initiation　TLN：total leaf number
V.S.：vegetative stage　R.S.：reproductive stage

Table 8. Heterosis percentage for growth and differentiation characters of maize grown in the fall crop season.

Combination	Hybrids	Days from S.E. to T.I. (day)	Leaf number at T.I. (leaves)	LAR in the V.S. (leaves/day)	Days from T.I.to E.I. (day)	LAR in the R.S. (leaves/day)	L.I. rate (leaves/day)	TLN (leaves)	Leaf area per plant (cm^2)	Dry weight at dough stage (g/5-plant)
Dent	A x B	−8.0	−0.6	8.4	30.5	−1.8	11.1	1.4	0.0	2.9
x	A x C	−16.5	−0.9	19.0	78.8	9.3	29.3	7.6	20.9	27.4
Dent	B x C	−17.4	−2.0	18.6	54.3	6.7	22.7	1.2	18.1	18.5
	x̄	−14.0	−1.2	15.3	54.5	4.7	21.0	3.4	13.0	16.3
Flint	D x E	−9.7	−1.6	39.5	86.7	−11.6	9.6	−0.8	36.1	59.9
x	D x F	−11.8	3.6	18.3	77.9	−5.2	16.9	3.3	27.2	81.8
Flint	E x F	−12.0	6.5	19.4	68.3	6.5	18.9	5.9	5.4	79.1
	x̄	−11.1	2.8	25.7	·77.6	−3.4	15.1	2.8	22.9	73.6
	A x D	−15.1	−4.3	12.3	86.5	−1.3	21.6	3.6	48.3	91.8
	A x E	−16.2	1.2	20.2	76.5	11.1	24.7	4.3	28.5	48.4
	A x F	−8.3	5.9	15.5	42.8	8.7	15.1	5.4	25.9	98.5
	B x D	−9.7	0.0	11.3	48.7	−14.1	6.7	−3.8	51.9	57.6
Dent	B x E	−16.5	−1.4	18.1	64.2	7.6	20.2	0.4	28.1	50.1
x	B x F	−6.6	7.3	15.7	12.9	5.4	7.4	0.0	16.4	62.7
Flint	C x D	−18.0	−4.3	16.7	92.6	−10.4	22.5	0.8	44.8	69.4
	C x E	−15.7	1.4	19.4	94.0	−3.3	19.8	1.0	27.0	52.2
	C x F	−10.1	4.4	16.3	41.5	11.9	19.9	7.2	9.5	57.9
	x̄	−12.9	1.1	16.2	62.2	1.7	17.6	2.1	31.1	65.4
S.E.		3.8	3.7	6.8	24.4	8.6	6.6	3.2	15.1	26.2

S.E. : seedling emergence　LAR : leaf appearance rate　L.I. : leaf initiation
T.I. : tassel initiation　E.I. : ear initiation　TLN : total leaf number
V.S. : vegetative stage　R.S. : reproductive stage

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Effects of Crop Seasons on the Combining Ability Expression of Growth and Differentiation Trait between Dent and Flint Combination Type of Maize[1].

G. J. Shieh[2] and F. S. Thseng[3]

Summary

A diallel study including three inbred lines each of dent and flint maize as parents were grown in the spring and fall crop seasons. Level of heterosis, estimate of genetic effects, and genetic variance for some growth and differentiation traits were investigated and compared among genotypes with flint, dent, and flint x dent kernel types. Results from dialled analysis indicated that mean squares of GCA and SCA were significant for most traits investigated. Reciprocal effect also existed for all traits except leaf appearance rate in the vegetative stage. The ratio of GCA/SCA variances (〉 1) suggested that additive variance was prediminant to non-additive variance in both crop seasons. However, the ratio of GCA/SCA variance was variable when comparison was made between spring and fall crops. For GCA effects while flint inbreds showed positive effects for most traits. On the other hand, GCA effects for leaf number at tassel initiation and days from tassel initiation to tassel emergence were larger in the spring crop whereas those for other traits were larger in the fall crop season. SCA effects were predominantly positive in flint x dent crosses and negative in dent x dent and flint x flint crosses for most traits under the spring crop condition. On the contrary, SCA effects of most traits were negative for all three combination types in the fall crop season. Furthermore, dent x dent hybrids were larger than flint x flint hybrids in heterosis for most traits in the spring crop. Dent x flint hybrids were larger than dent x dent and flint x flint hybrids in heterosis for LAR in the vegetative stage, leaf initiation rate, leaf area per plant, and whole-plant dry weightat at dough stage in the spring crop. The expression of other traits of dent x flint crosses was intermediate between flint x flint and dent x dent crosses. In the fall crop season, flint x flint hybrids were larger than dent x dent hybrids in heterosis for most traits, and heterosis of dent x flint crosses was intermediate between flint x flint and dent x dent crosses. In other words, heterosis of the same combination type was variable in different crop seasons.

Key words : Corn (*Zea mays* L.) Crop season, Dent, Flint, General combining ability, Specific combining ability, Reciprocal effect, Heterosis.

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1. Contribution No. 1664 from Taiwan Agricultural Research Institute.
2. Assistant Agronomist, Department of Agronomy, TARI, Wufeng, Taichung Hsien, Taiwan 413, ROC.
3. Professor Department of Agronomy, National Chung-Hsing Univessity, Taichung. Taiwan, ROC.

Jour. Agric. Res. China (中華農業研究) 42(2): 146~153 (1993)

Influence of weed interference on the growth and yield of no-tillage corn (*Zea mays* L.)[1]

Chwen-Ming Yang, Hung-Shung Lu and Fu-Chou Chang[2]

Abstract: Field experiments were conducted at the experimental farm of Taiwan Agricultural Research Institute (TARI) to study the influence of weed interference periods on the growth and yield of no-tillage corn (*Zea mays* L. cv. Tainung No. 1) in the fall crop of 1991 and the spring crop of 1992. Corn was strip planted and weed interference duration ranged from 1 week after planting to full-season with weed-free check as control. It showed that more weeds were collected from corn field in Fall than in Spring. Plant height and leaf number were not significantly affected by weed interference, whereas leaf area as well as leaf weight was declined, particularly over 6 weeks of interference. The 50% tasseling and silking dates were not changed by the existence of weeds. The effective plant percentage (EPP) measured at harvest ranged from 64 to 74% and 74 to 85% in the fall crop and the spring crop, respectively. The yield of corn was reduced when duration of weed interference was more than 4 weeks, a 20% reduction of yield was resulted from 6 weeks of weed interference in 1991 and 8 weeks in 1992. It is summarized that acceptable corn yield may be maintained when weed interference was less than 6 weeks after planting under no-tillage conditions.

Key words: Weeds, Interference duration, Corn, Growth, Yield, No-tillage.

INTRODUCTION

It is a primay concern of corn producer to reduce the production costs. Corn planted in no-tillage field is one of the cultivation systems actually practicing in Taiwan for this purpose. Sheu and Chu (1991) estimated that there was an average of 15% decrease of grain yield of corn under no-tillage than that from tillage one, but the total expenses were 13% less. Weed control program and pest management that reduce weed interference on crops within the growing season are two other practices in improving the possible potential yield in no-tillage corn.

Knowledge of effect of weed interference periods on crop yield is improtant for understanding the consequences that may result from the exposure of weed infestations and for

1. Contribution No. 1665 from Taiwan Agricultural Research Institute. This work was spported by the Council of Agriculture under grant 81-Nung Chien-12. 2-Foods-47(4).

2. Agronmist, Senior Agronomist, and Assistant, Department of Agronomy, Taiwan Agricultural Research Institute, Wufeng, Taichung Taiwan 413, Republic of China.

determining the duration that becomes economically detrimental. Sniper *et al.* (1987) reported that cotton yield was adversely affected by weeds when allowed to compete longer than 4 weeks. Wilson and Cole (1966) and Wyse *et al.* (1986) indicated that weeds must be removed by 6 to 8 weeks after emergence to prevent soybean yield reduction. How and when corn be apt to the influence of weeds in no-tillage has not been investigated and is essential for adequately applying weed practices.

The objectives of this research were to study the influence of weed interference periods on no-tillage corn growth and to determine the length of time that weed control practices could be delayed without reducing corn yield.

MATERIALS AND METHODS

The experiments were conducted at the experimental farm of Taiwan Agricultural Research Institute (24°02′ N, 120°40′ E, elevation 85 m) on a loam soil (fine-loamy, mixed, nonacid, hyperthermic, Fluvaquentic Dystrochrept) in Fall crop 1991 and Spring crop 1992. The soil contained 25.1% sand, 48.8% silt, and 26.0% clay with 1.44% organic matter and a pH of 5.3. Corn cultivar 'Tainung No. 1′ was purchased from Taiwan Seed Service (Ta-nan village, Shinshieh, Taichung, Taiwan, ROC) and was strip planted at a depth of about 4 cm and with plant distance of 25 cm on 15 July 1991 and 8 January 1992, respectively. The subplots were 5.5 m by 7.0 m with 8 rows spaced 70 cm apart. The experimental plots were prepared more than six months before planting and weed populations were the result of natural infestations. Duration of weed interference ranged from 1, 2, 4, 6, 8 and 10 weeks after planting to full-season (weedy check) with weed-free check (0 week) as control. Weeds were removed by hands from the experimental plots at the desired periods and the plots were handweeding every two weeks to keep weed free since then. The weather data were obtained from the weather station at TARI.

Fertilizer (60-90-60 kg ha^{-1} ; N-P_2O-K_2O) was applied onto the soil surface at planting and additional 90 kg ha^{+} of nitrogen was applied with equivalent at 3, 6 and 9 weeks after planting. Pesticide 2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methyl-carbamate (3% granule, 30 kg ha^{-1}) was applied on soil surface after planting and was sprayed on the canopy using 40.64% fluid at a rate of 1.2 L ha^{-1} at 5 weeks after planting.

Six plants were sampled from each replication and plant height, leaf number, leaf area and plant dry weight were measured at the 50% of silking. Plant height was measured with a ruler stick and leaf area was determined by an area meter (LI-3000, Li-Cor, Inc., Nebraska, USA). Dry weights of root, stem and leaf were measured after oven-dried at 80 °C for 72 h. The effective plant percentage (EPP) at harvest was calculated by counting the number of plants with ear (s) in each subplot relative to the planted number expressed as a percent of the planted number. Corn yields were estimated by dry weight of ears (without husk) taken from the center two rows of each eight-row subplot by hands on 18 October 1991 and 20 May 1992, respectively. A square meter of weeds were collected from the weedy check periodically and their dry weights (oven-dried at 80 °C for 72 h) were recorded.

The experiment was a randomized complete block design with three replications. Data were subjected to analysis of variance and means were compared with Fisher's Least Significant Difference (LSD) Test at the 5% level of probability. The standard errors were

also computed.

RESULTS AND DISCUSSION

Weed interference is a major limiting factor in growing corn in no-tillage field with natural infested weeds. Adequate timing to apply weed control practices before weeds starting great impct on cron growth and yield is therefore need to be determined and is an important information required for reaching the possible potential yield.

The weather conditions during corn growth in Fall 1991 and Spring 1992 were shown in Figure 1, in which the monthly values of irradiance, daily mean temperature and precipitation were recorded. Data showed that a distinct climate was presented in either crop, which not only changed the growth pattern of corn but provided various climatic environment for weed infestations. In general more weeds were collected in Fall than in Spring during the growing seasons (Table 1). Consequently, Fall crop experienced greater impact from weed interference as that reflecting in the harvested yields (Table 5). Weed density effect has been reported in other crops such as soybean and cotton (Bloomberg *et al.*, 1982 ; Buchanan and Burns, 1971 ; Harrison, 1990 ; Wilson and Cole, 1966).

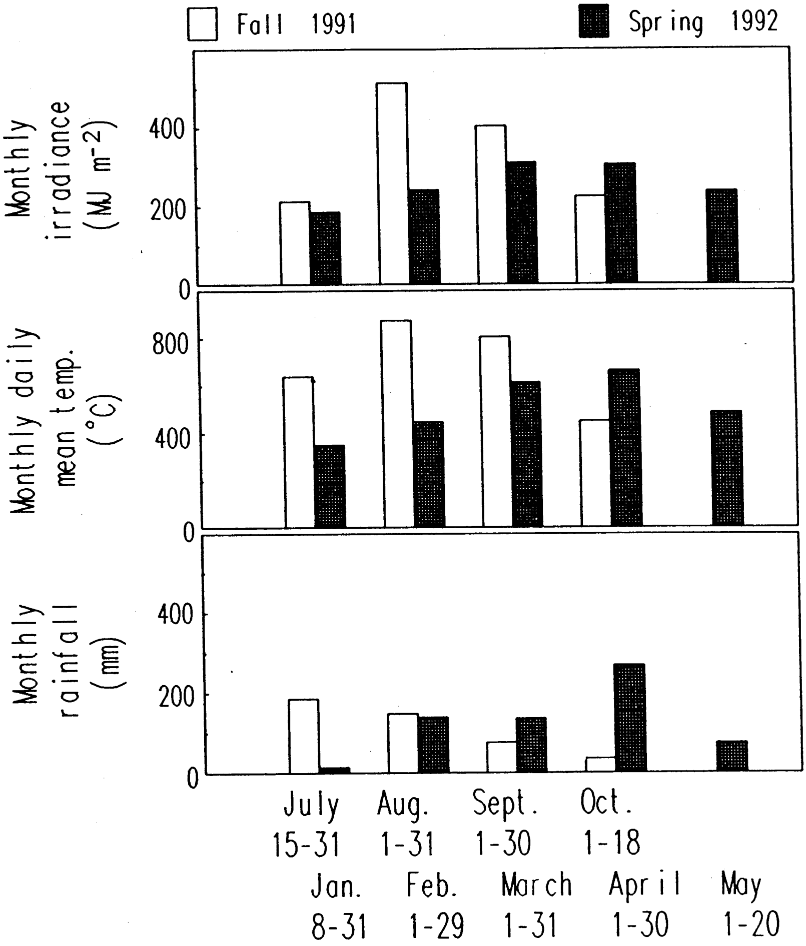

Fig. 1. The weather data during the growing seasons of fall crop of 1991 and spring crop of 1992.

Table 1. Mean and standard error of dry weight of weeds collected from no-tillage corn field during the crop seasons of 1991 and 1992.

Crop Season	Sampling date	Weed dry weight
		gm^{-2}
Fall 1991	July 15	451.25±88.54
	Aug. 8	399.81±56.98
	Sept. 10	574.70±64.28
	Oct. 18	574.70±64.28
Spring 1992	Jan. 8	331.76±74.69
	Feb. 13	338.39±40.59
	March 18	324.50±34.58
	April 20	387.42±37.79
	May 20	440.40±23.62

Growth characteristics and plant weights measured at the 50% of silking as influenced by weed interference periods were listed in Tables 2 and 3. It indicated that duration of weed interference longer than 4 weeks in Fall and 8 weeks in Spring significanly affected leaf area and plant weight, especially leaf weight. Since leaf number per plant was not affeced, leaf size was smaller, which in turn reducing the photosynthetic capacity and dry matter production. Bloomberg *et al.* (1982) pointed out that soybean yield reduction by weeds was through the decrease of total dry weight and number of pods per plant. Interference duration of 40 days or longer reduced the panicles per square meter, culms per square meter, and yield of rice (McGregor, Jr. *et al.*, 1988).

Table 2. Weed interference on some growth characteristics of no-tillage corn "Tainung No. 1" measured at the 50% of silking on 18 September 1991 and 20 April 1992.

Crop season	Duration of interference	Plant height	Leaf number	Leaf area
		cm	No. pl^{-1}	cm pl^{-1}
Fall 1991	Weed-free	223.1	11.3	5,064
	1 Week	224.2	10.3	4,824
	2 Weeks	221.5	9.7	4,548
	4 Weeks	217.9	9.3	4,449
	6 Weeks	216.1	9.3	4,241
	8 Weeks	216.0	9.7	4,412
	10 Weeks	213.2	9.3	4,388
	Weedy check	212.8	9.3	4,081
LSD (0.05)		13.5	1.7	497
Spring 1992	Weed-free	219.0	11.9	4,848
	1 Week	221.6	11.7	4,771
	2 Weeks	218.7	11.6	4,748
	4 Weeks	220.9	11.4	4,644
	6 Weeks	215.4	11.1	4,500
	8 Weeks	216.8	10.9	4,364
	10 Weeks	217.6	10.6	4,083
	Weedy check	216.8	10.5	3,970
LSD (0.05)		14.4	1.3	454

Table 3. Weed interference on dry weights of no-tillage corn "Tainung No. 1" measured at 50% of silking on 18 September 1991 and 20 April 1992.

Crop season	Duration of interference	Dry weight			sum
		leaf	stem	root	
		g pl^{-1}			
Fall 1991	Weed-free	39.30	65.24	23.62	128.15
	1 Week	37.80	64.95	23.07	126.49
	2 Weeks	35.69	64.44	22.58	122.70
	4 Weeks	34.75	64.80	22.29	121.84
	6 Weeks	33.42	62.21	20.91	116.54
	8 Weeks	34.70	62.46	20.78	119.30
	10 Weeks	32.12	61.39	21.02	116.52
	Weedy check	32.42	61.09	20.28	113.80
LSD (0.05)		3.67	7.13	3.84	7.91
Spring 1992	Weed-free	35.64	70.92	22.29	128.85
	1 Week	35.07	70.60	22.93	128.60
	2 Weeks	34.90	69.13	21.67	125.70
	4 Weeks	34.13	66.46	21.65	122.24
	6 Weeks	33.06	66.40	20.61	120.07
	8 Weeks	32.07	65.53	19.34	116.94
	10 Weeks	30.14	58.65	16.55	105.34
	Weedy check	29.32	54.02	17.00	100.34
LSD (0.05)		3.27	1.58	1.93	4.20

The development of corn, however, was not significantly altered by weeding periods. The dates of the 50% tasseling and the 50% of silking occurred on September 4 to 7 and April 17 to 20 in Fall crop and Spring crop (Table 4), respectively. Similar values of the effective plant percentage were calculated among treatments at harvest, ranged from 64 to 74% and 74 to 85% in the fall crop and the spring crop, respectively, which implied that weed interference periods did not affect no-tillage corn stands establishment.

The yield of corn was evaluated by dry weight of ears harvested from the experimental plots (Table 5). Corn yield was not reduced until duration of weed interference was more than 4 weeks after planting. For example, a 20% reduction of yield was resulted from 6 weeks of weed interference in 1991 and 8 weeks in 1992. Although the effects of duration of interference may vary with different weed species (Smith, Jr., 1968), this study demonstrated that duration of weed interference may affect corn growth and yield in a natural-infestated field in both the fall and the spring growing seasons. Weed control practices should be applied before 6 weeks after planting to prevent further corn yield reductions.

Table 4. Weed interference on the 50% tasseling and the 50% silging dates and the effective plant percentage (EPP) calculated at harvest of no-tillage corn "Tainung No.1."

Crop season	Duration of interference	50% Tasseling	50% Silking	EPP (%)
Fall 1991	Weed-free	Sept. 4	Sept. 6	73.7
	1 Week	Sept. 4	Sept. 6	68.1
	2 Weeks	Sept. 4	Sept. 6	66.3
	4 Weeks	Sept. 5	Sept. 7	65.8
	6 Weeks	Sept. 5	Sept. 7	63.8
	8 Weeks	Sept. 4	Sept. 6	63.0
	10 Weeks	Sept. 4	Sept. 6	64.3
	Weedy check	Sept. 4	Sept. 6	63.9
LSD (0.05)				10.8
Spring 1992	Weed-free	April 18	April 19	84.5
	1 Week	April 18	April 19	84.9
	2 Weeks	April 19	April 20	82.1
	4 Weeks	April 18	April 20	78.9
	6 Weeks	April 19	April 20	77.9
	8 Weeks	April 19	April 20	77.4
	10 Weeks	April 17	April 18	75.4
	Weedy check	April 17	April 19	74.2
LSD (0.05)				10.6

Table 5. Weed interference on dry weight of ears (yield) of no-tillage corn " Tainung No. 1" at harvest.

Crop season	Duration of interference	Ear dry weight (kg/ha)	index (%)
Fall 1991	Weed-free	4,260	100
	1 Week	4,040	95
	2 Weeks	3,980	93
	4 Weeks	3,580	84
	6 Weeks	3,400	80
	8 Weeks	3,440	81
	10 Weeks	3,310	78
	Weedy check	2,760	65
LSD (0.05)		650	
Spring 1992	Weed-free	5,230	100
	1 Week	5,330	102
	2 Weeks	4,750	91
	4 Weeks	4,630	89
	6 Weeks	4,570	87
	8 Weeks	4,260	81
	10 Weeks	3,910	75
	Weedy check	3,980	76
LSD (0.05)		420	

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雜草干擾時期對不整地栽培玉米生長與產量的影響[1]

楊純明　盧煌勝　張富洲[2]

摘　要

本文研究旨在探討雜草干擾時期對不整地栽培玉米之生長與產量的影響，田間試驗分別於1991年秋作及1992春作在臺灣省農業試驗所農場進行。玉米臺農一號採條播穴植，雜草干擾時期則分從玉米播後一週至全生育，計有七種處理，而以全期無雜草干擾爲對照組。根據試驗結果，自秋作玉米田區收集之雜草量平均大於取自春作區者。雜草干擾未顯著限制玉米株高及葉片數，葉面積及植株乾重則減少，尤其當干擾時期超過 6 週以上。達到50%雄穗開花及雌穗吐絲所需日期，亦不受雜草干擾改變。收穫時，玉米有效植株百分比雖未顯著差異，但其差距高達10%；當干擾時期超過播種後4週，產量將降低，其中秋作干擾時期達 6 週及春作達 8 週時，將有20%的減產。

關鍵詞：雜草、干擾時期、不整地、玉米、生長、產量。

1. 臺灣省農業試驗所　研究報告第 1665 號。本研究承蒙行政院農業委員會補助試驗經費（81-農建-12.2-糧-47(4)），謹此誌謝。
2. 臺灣省農業試驗所農藝系副研究員、研究員及助理。臺灣省　臺中縣　霧峰鄉。

中華農業研究（Jour. Agric. Res. China）42(2)：154～161（1993）

薑黃之生長與發育

I.根莖之形成及各次位分生子莖之成分分析[1]

邱善美　劉慧瑛　朱戩良[2]

摘要：本試驗以薑黃（*Curcuma aromatica* Salisb.）大黃種爲材料，調查分生子莖之形成過程，並分析比較各次位分生子莖間之成分組成及品質。試驗結果顯示薑黃分生子莖之形成約始於第二葉（完全展開葉）期，而後隨葉片數的增長而增加，至葉鞘出土後145天（收穫期），每株平均分生子莖數高達114.7個，其中各次位之平均分生子莖數，依其多寡次序爲第三次51.7個，第二次35.6個，第四次19.6個，及第一次7.8個，各約佔總根莖數之45.1、31.0、17.1及6.8%。薑黃根莖含多量碳水化合物（55—64%），與分生子莖比較，母莖之澱粉含量較低，但可溶性糖類含量較高；此外，母莖之粗蛋白質含量（17.8%）亦明顯高於分生子莖（5.1—13.1%）。在薑黃素含量方面，依其高低順序爲母莖0.55%，第一次分生子莖0.49%，第二次分生子莖0.43%，及第三次分生子莖0.31%，顯示愈早形成之根莖，其薑黃素含量愈高，對品質之提升有利，反之，高次位分生子莖之薑黃素含量低，品質亦較劣。

關鍵詞：薑黃、薑黃素、根莖、分生子莖、化學組成。

薑黃（*Curcuma aromatica* Salisb.）屬薑科（Zingiberaceae），爲多年生草本植物，其主要被利用部分爲根莖（rhizome）。數世紀以來即被用爲消炎劑，具暢通血液循環，消散瘀血、治月經不調、胃潰瘍出血及止心絞痛等藥效[1,2,4,6,8,9]，近年來更有學者研究發現薑黃素（curcumin）含抗氧化性物質，極有可能具有抑制 TPA （12-0-teradecanoyl phorbol-13-acetate）致癌作用的能力[5]。在另一方面，由於其根莖內含類似腊狀光澤的橙黃色素及類似生薑之芳香苦味，除供食品著色外，兼具辛香特性，爲瓜類鹽醃加工食品主要著色劑和防腐作用，更爲咖哩粉中唯一辛香佐料，市場需求殷切。

薑黃之根莖係母莖（mother set）及分生子莖（finger）之總稱，前者粗壯膨大，呈圓錐形，爲著生分生子莖之母體；後者如手指狀，俗稱指莖[7]。但不論係母莖或分生子莖，都具有環節，節間短，肉呈黃色或橙黃色，味芳香略苦。由於分生子莖著生部位的不同，又有第一次分生子莖（自母莖長出）、第二次分生子莖（自第一次分生子莖長出）及第三次分生子莖（自第二次分生子莖長出）等不同次位之別。就各次位分生子莖之分化期而言，以母莖之分化期最早，次爲第一次分生子莖，及隨後之第二次與其他各次位分生子莖；如在同一日收穫，亦以母莖之生育期最長，其他各次位分生子莖之生育期較短。因此薑黃根莖之成分組成，尤其是薑黃素含量，除品種及栽培環境之影響外，在各次位分生子莖間是否具有差異，是頗值得探討的問題。本試驗係以本省薑黃品種「大黃種」爲材料，於本所農場栽培，調查分生子莖的形成過程，同時分析各項化學成分組成，比較其間差異，以供今後栽培及利用之參考。

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1. 臺灣省農業試驗所研究報告　第 1666 號。本試驗進行期間承本所作物生理研究室提供部份器材，謹此致謝。
2. 本所農藝系研究員與農業化學系副研究員及助理。臺灣省　臺中縣　霧峰鄉。

材料與方法

一、試驗材料：薑黃品種大黃種。

二、材料之培育：

供作種用之根莖於1991年元月收穫，置入尼龍網袋，存放於溫室通風走道約三個月，其間未發現有萌芽現象。種植前一天以刀片分取第一次分生子莖爲種苗，俟傷口乾燥後於同年4月18日種植於本所試驗農場，土質爲坋質壤土；田間採用完全逢機區集法設計，4重複，試區行長6m，行距60cm，株距30cm，每行20株，5行區，每小區計100株。肥料施用量 N：P_2O_5：K_2O＝90：40：100kg/ha，其中以磷肥全量及氮、鉀肥之三分之一量於種植前一天施用爲基肥，剩餘三分之二量於行第一次（6月20日）及第二次（7月16日）中耕培土時平均施用爲追肥。生育期間曾行畦面淹水灌溉三次（分別爲7月2日、7月24日及8月19日），收穫期爲1992年1月21日。

三、根莖（第一次分生子莖）形成調查：

在植株生育過程中，於第1、2、3、4及5葉完全展開時，不分重複逢機選取植株10株，洗淨根部泥土雜物，以肉眼觀察，計數分生子莖形成數。

四、各次位分生子莖之成分分析：

於試區內全部植株之地上部莖葉枯萎倒伏後，每重複分別收穫中間行20株之根莖，洗淨泥土，再依各分生子莖著生次位，分別收穫；以尼龍網袋盛裝，置入80°C烘乾箱中烘乾72小時以上，使完全乾燥，再以磨粉機磨粉，供化學分析之用。各項分析方法如下：

㈠粗蛋白質：以 semi-micro Kjeldahl 法測定全氮含量，而以 N%×6.25表示之。

㈡粗脂肪：用 Soxhlet 裝置以乙醚抽出18小時後測定。

㈢游離糖：將樣本以約50倍之80%乙醇加熱（80—85°C）迴流30分鐘，連續進行四次，殘渣以80%乙醇洗滌並與前四次之抽出液合併，經玻璃棉過濾後，以酚—硫酸法測定糖含量[12]，而以葡萄糖爲標準。

㈣粗澱粉：將樣本以 0.75 N 鹽酸加熱（100°C沸水浴）迴流2小時水解澱粉後，將殘渣以水洗滌並與水解液合併以 Whatman GF/A 玻璃棉濾紙過濾；濾液以酚—硫酸法測定全糖含量[12]，而以葡萄糖爲標準。將全部糖含量減去游離糖含量後之數值乘以0.9即爲粗澱粉含量。

㈤醣類組成：取0.5g 樣本以5ml之80%乙醇加熱迴流抽取游離糖兩次後，用玻璃棉濾紙過濾，於所得殘渣加入約5ml之 0.75N HCl 在沸水浴中加熱2小時，再以玻璃棉濾紙過濾，濾液以高效液相層析儀（Hitachi L—6,000）分析，使用 RI detector、Hitachi D-2,000integrator 及 Li-Chrosopher 100-NH2 column (5 um, 4.0×250mm)，effluent 爲acetonitrile/H_2O (80/20)，flow rate 爲1ml/min；糖標準爲 Sigma 公司之 No. Car-11 carbohydrate kit。

㈥礦物質組成：樣本先經高溫灰化，以3N HCl溶解及蒸餾水稀釋後，用感應耦合電漿—原子發光光譜儀（Jobin-Yvon 38 Type III inductivity coupled plasma-atomic emission spectrophotometer）測定 P、Ca、Mg、Fe、Mn、Cu 及 Zn 含量，以火焰光度計（Corning Model400 flame photometer）測定 Na 及 K 之含量。

㈦薑黃素：依據陳與蔡[3]及蔡與陳[7]之方法，將樣本以95%乙醇萃取至抽出液不再呈黃色後，測定抽出液在430nm波長之吸光度，而以 Sigma 公司 C—1386薑黃素爲標準換算之。

以上各項成分分析均爲四重複，以平均值表示之，並進行變方分析，比較其差異顯著性。

結果與討論

以未經催芽或經催芽處理之薑黃根莖爲種苗種植，至葉鞘伸出土面所需之時間，並無確切資料可

憑參考；Singh and Randhawa[11]在印度觀察之結果指出「需一段頗長之時間」；在亞熱帶地區，一般認爲較高的氣溫有利於薑黃根莖萌芽[12]。本省薑黃種植適期約爲三月下旬至四月上中旬，可能亦係基於氣溫的考量，過早種植因低溫導致萌芽時日之延長，不利於田間管理作業。本試驗以未經催芽之根莖，於1991年4月18日種植，同年5月12日在葉鞘尚未伸出土面前，由於雜草及土壤乾旱關係，曾行除草及畦面淹水灌溉一次。田間調查資料顯示，葉鞘出土期約始於種植後35天，但遲至6月9日，即種植後約50日，各重複葉鞘出土株數方達90%左右；顯示薑黃之根莖如未經催芽處理即於4月中旬予以種植，葉鞘出土甚爲緩慢，整齊度亦不理想，自葉鞘出土始期至終期約需16天左右。

薑黃於生育過程中自母莖依次生成一次、二次等不同次位分生子莖（圖1）。由母莖形成第一次分生子莖之時期與地上部生育的關係，尚無資料可供參考。本試驗於第1葉期至第5葉期（完全展開葉）連續五次採取薑黃植株，調查第一次分生子莖數目，所得結果列如表1；結果顯示在本所農場栽培環境下，薑黃大黃種分生子莖之形成期約在第二葉片完全展開後至第三葉片尚未顯露前，在10株供調查之材料中，有4株各形成1個分生子莖；生育至第三葉期時，有1株形成2個分生子莖，其餘9株各形成1個分生子莖；嗣後分生子莖數目隨葉片數的增加而增多；至植株生育至具有第5葉片時，每株第一次分生子莖數最多達4個，最少爲2個，平均每株3.1個。收穫時（1992年1月21日）調查每株各次位分生子莖數目，以第三次分生子莖所佔比率最高（45.1%），次爲第二次分生子莖（31.0%），而以第一次及第四次者較少，分別爲6.8%及17.1%（表2）。

圖1. 薑黃大黃種各次位分生子莖在母莖上著生情形；數字1—4分別表示母莖及第1次位至第3次位之分生子莖

Fig 1. The growth position of different orders of finger set of turmeric rhizomes. Numbers 1, 2, 3 and 4 indicate mother set and primary, secondary, and tertiary finger sets, respectively.

表1. 薑黃大黃種分生子莖之形成與葉數之關係

Table 1. The relationship between numbers of fully-expanded leaves and initiated primary fingers of turmeric rhizomes cultivated at TARI in 1991.

Number of fully-expanded leaves	Number of primary fingers Plant number 1	2	3	4	5	6	7	8	9	10	Total
1	0	0	0	0	0	0	0	0	0	0	0
2	0	1	1	0	1	0	1	0	0	0	4
3	2	1	1	1	1	1	1	1	1	1	11
4	2	2	1	2	2	2	2	1	2	1	17
5	3	3	2	4	3	3	3	4	3	3	31

表2. 薑黃大黃種之各次位分生子莖數及其百分比。

Table 2. Numbers and percentage (in parenthesis) of different orders of finger set of turmeric rhizomes cultivated at TARI in 1991.

Primary finger set	Secondary finger set	Tertiary finger set	Quaternary finger set	Total
7.8 (6.8)	35.6 (31.0)	51.7 (45.1)	19.6 (17.1)	114.7 (100.0)

根莖內黃色素之生成與累積，似與分生子莖之形成同步，以不同生育期之根莖進行橫切面觀察，於較幼嫩之第三次分生子莖內可見一細小呈淡黃色之色環，第一次分生子莖及母莖則具有較大之色環（圖2），亦即色環隨根莖之成長與發育，逐漸向周邊擴張增大，最後充實整個根莖；顏色亦自淡黃轉變為橙黃。

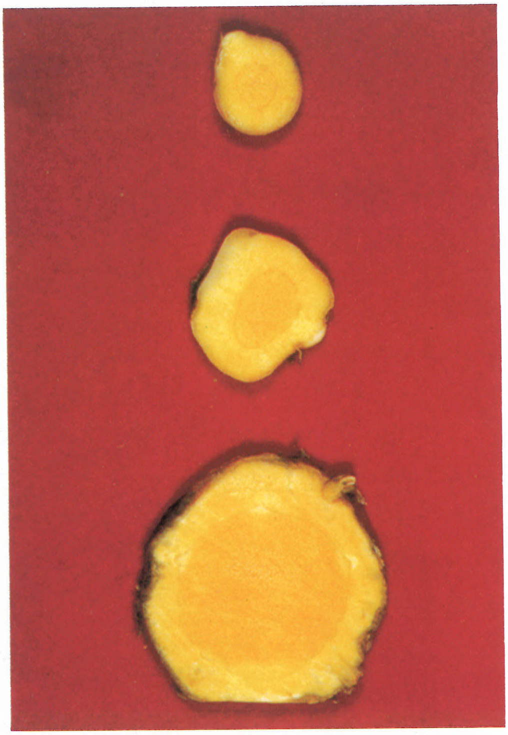

圖2. 薑黃大黃種黃色素之生成

Fig 2. Acccumulation pattern of yellow pigments in mother set (lower), primary finger set (middle), and tertiary finger set (upper) of turmeric rhizomes.

薑黃根莖所含之薑黃素不溶於水，但溶於酒精或冰醋酸；在酸中呈黃色，在鹼中則呈棕紅色。薑黃素含量之測定多以酒精抽出後，測其在波長420或430nm 的吸光度而計算之[7,12]。本試驗以不同次位分生子莖測得之薑黃素含量及一般成分組成列如表3。在薑黃素含量方面，以母莖含量（0.55%）最高，依次爲第一次（0.49%）、第二次（0.43%）及第三次分生子莖（0.31%），處理間差異顯著，顯示早期形成的分生子莖較晚期形成者具有較高的薑黃素含量；但母莖與第一次分生子莖間及第一次與第二次分生子莖間，薑黃素含量差異並未達5%顯著水準。本試驗供試品種爲大黃種，各次位分生子莖個體數以第三次分生子莖最多，但薑黃素含量最低（0.31%），就整體而言，勢必影響根莖品質。蔡與陳[7]以自印尼及泰國等地區引入之薑黃爲材料，測定不同品種（系）間薑黃素含量之差異，結果顯示薑黃素含量分布於1.5—5.4%之間，則本省之大黃種薑黃素含量遠遜於印尼及泰國種。又薑黃素係含於根莖之脂質中，母莖與一次分生子莖的薑黃素含量雖然較高，粗脂肪含量卻最低，反之，第三次分生子莖的脂肪含量高，薑黃素含量卻最低，是否在根莖發育過程中，兩項成分的合成具有時序性差異，或就量的關係而言，兩者之間有負相關關係存在，尙難予以確定，由於此項資料對決定薑黃品質具有重要性，有待進一步試驗予以證明。

表3. 薑黃大黃種不同次位分生子莖主要成分含量比較（%，乾重基準）

Table 3. Chemical composition of different orders of finger set of turmeric rhizomes cultivated at TARI in 1991 (%, dry weight basis)

Order of finger set	Curcumin	Crude protein	Crude fat	Soluble sugars	Starch
Mother set	0.55^{a*}	17.84^{a}	2.49^{bc}	17.21^{a}	40.39^{c}
Primary set	0.49^{ab}	13.14^{b}	2.04^{c}	11.04^{c}	44.45^{b}
Secondary set	0.43^{b}	7.38^{b}	2.70^{ab}	13.12^{b}	50.61^{a}
Tertiary set	0.31^{c}	5.12^{b}	3.29^{a}	13.38^{b}	50.29^{a}

* Means followed by the same letter within each column are not significantly different at 5% level by Duncan's multiple range test.

表3資料同時顯示薑黃根莖之組成分中，以澱粉的含量最高，母莖爲40.39%，較第一次分生子莖（44.45%）爲低，又次於第二次及第三次分生子莖，糖類與粗脂肪含量在各次位分生子莖間的變化趨勢也有相同表現。在粗蛋白質含量方面，則以母莖最高，高次位分生子莖最低，例如母莖粗蛋白質含量（17.84%）爲第三次分生子莖含量（5.12%）的三倍以上。

各次位分生子莖之礦物質組成成分列如表4。在所分析的九個元素中，以 K 的含量最高，依次爲 P、Mg、Ca 及各微量元素。如以各次位分生子莖間比較，除 K 及 Na 以第二次分生子莖含量顯著的高於其他各次位分生子莖外，Ca、Mg、Fe、Mn、Cu 及 Zn 等元素均以母莖之含量顯著的高於其他分生子莖，P 含量雖亦有相同趨勢，但各次位分生子莖間的差異未達顯著水準。

表4. 薑黃大黃種不同次位分生子莖礦物元素含量比較（mg/100g，乾重基準）

Table 4. Mineral concentrations of different orders of finger set of turmeric rhizomes cultivated at TARI in 1991 (mg/100g, dry weight basis)

Order of finger set	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
Mother set	672^{a*}	1,480^{c}	149^{a}	535^{a}	54.5^{ab}	12.6^{a}	54.5^{a}	6.1^{a}	19.1^{a}
Primary set	561^{a}	2,227^{b}	105^{b}	372^{b}	44.5^{b}	9.8^{b}	23.5^{b}	2.3^{b}	7.4^{b}
Secondary set	515^{a}	3,930^{a}	104^{b}	286^{c}	63.3^{a}	9.1^{b}	4.5^{c}	0.7^{b}	2.4^{c}
Tertiary set	429^{a}	2,440^{b}	101^{b}	219^{c}	50.3^{b}	7.2^{b}	2.0^{c}	2.1^{b}	2.9^{c}

* Means followed by the same letter within each column are not significantly different at 5% level by Duncan's multiple range test.

薑黃屬根莖作物，而這類作物的根莖部位常是貯藏聚醣（polysaccharides）的場所。植物的聚醣因構成的單糖種類不同而有差異，例如澱粉爲葡萄糖構成的葡萄聚醣，菊醣（inulin）或左聚醣（levan）爲果糖構成的果聚醣等。本試驗中以高效液相層析儀分析母莖與不同次位分生子莖經稀酸水解液的糖類組成（圖3），得知薑黃母莖與分生子莖的貯藏性聚醣之糖類組成相同，以葡萄糖與麥芽糖爲主，亦即薑黃根莖的貯藏性聚醣主要爲澱粉；此外尙有少量的木糖（xylose）及阿拉伯糖（arabinose）存在，可知聚醣組成中尙含有少量的木聚醣及阿拉伯聚醣。又由分析圖中不含果糖及蔗糖（母莖含有微量蔗量）成分推斷，薑黃根莖內可能不含果聚糖。比較母莖與第三次分生子莖，發現兩者所含之木糖與阿拉伯糖比例並不相同；又母莖顯然較分生子莖含有較多之葡萄糖。

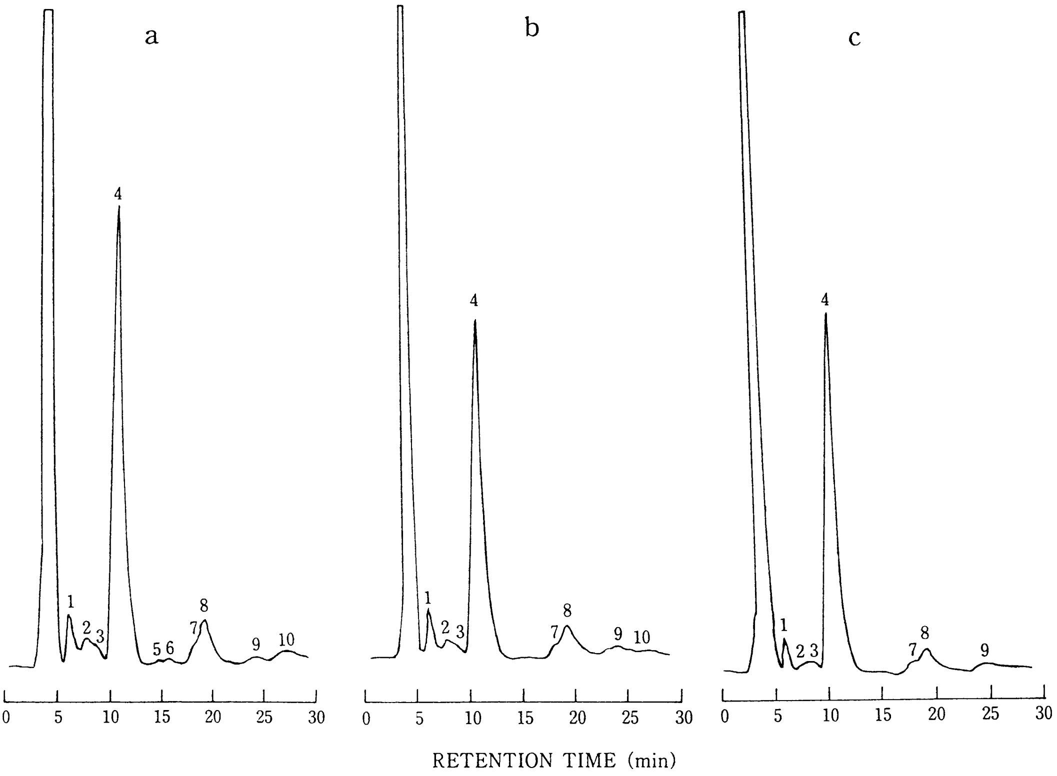

圖3. 薑黃大黃種母莖（a）與一次（b）及三次（c）分生子莖糖類之 HPLC 圖譜

Fig 3. HPLC chromatograms of sugars in mother set (a), primary finger set (b), and tertiary finger set (c) of trumeric rhizomes. Peaks 2, 3, 4, and 8 represent xylose, arabinose, glucose, and maltose, respectively.

綜合而言，本試驗結果顯示薑黃素之含量在不同次位分生子莖間確實存有差異，以母莖之含量高於其他各次位之分生子莖，第一次之分生子莖又高於第二次及第三次分生子莖，亦即早期形成之分生子莖歷經較長之生育期，有較高之薑黃素含量。因此，在選擇栽培品種時，應避免選擇第三次位以下分生子莖多的品種，以提高薑黃根莖品質。而在栽培技術的改進上，當控制品質欠佳高次位分生子莖之形成，或減少其個體數及重量，以促進低次位分生子莖之生長與發育。

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Growth and Development of Turmeric (*Curcuma aromatica* Salisb.) Plants

I . The Formation and Chemical Composition of Rhizome Finger Sets of Different Orders[1]

S. M. Chiu, H. I. Liu and C. L. Chu[2]

Summary

The sequential initiation and chemical composition of rhizome finger sets of different orders were investigated in *Curcuma aromatica* Salisb. The initiation of the primary finger set of rhizome started at the 2-leaf stage, and the number of the set increased with increasing leaf age. A total of 114.7 rhizomes per plant was recorded at harvest, or 145 days after the emergence of leaf sheath. Among these rhizomes, 7.8 were primary finger set, 35.6 were secondary finger set, 51.7 were tertiary finger set, and 19.6 were quaternary finger set, representing 6.8, 31.0, 45.1, and 17.1%, respectively, of the total rhizomes. Turmeric rhizomes were high in carbohydrate content (55-64%). Compared with finger sets, the mother set contained lower starch content but higher soluble sugar content. In addition, crude protein content was significantly higher for mother set (17.8%) than for finger sets (5.1-13.1%). Curcumin content was the highest (0.55%) in mother set, followed by the primary finger set (0.49%), secondary finger set (0.43%), and tertiary finger set (0.31%). The results indicated that early-formed rhizomes had higher curcumin content, and consequently better quality.

Key words : Turmeric (*Curcuma aromatica* Salisb.), Curcumin, Rhizome, Finger set, Chemical composition.

1. Contribution No. 1666 from Taiwan Agricultural Research Institute (TARI).
2. Respectively, Senior Agronomist, Department of Agronomy, and Agricultural Chemist and Research Assistant, Department of Agricultural Chemistry, TARI. Wufeng, Taichung, Taiwan 413, ROC.

中華農業研究（Jour. Agric. Res. China）42(2)：162～172（1993）

水田栽培檳榔心芋葉面積之簡易估算法[1]

陳烈夫[2]　呂椿棠[3]　呂秀英[3]　賴吉雄[2]

摘要：本研究之主要目的在探討臺灣本地栽培種檳榔心芋於水田栽培時之單葉面積的簡易估算方法，藉不同取樣時期的葉長及葉寬之測量，以尋找出一套精確、簡單、迅速且適用於整個生育期之簡易方式來估算葉面積。本試驗於1991年秋作在臺灣省農業試驗所試驗田區進行，自移植當天起至收穫爲止，每隔21天，逢機調查10株芋植株，分別測量各葉之葉面積（A）、沿著中肋由葉尖至葉基之最大長度（L_1）、葉尖至葉片裂刻之葉長（L_2）及最大葉寬（W）。結果顯示，由於芋葉的葉形在整個生長過程中大致維持固定，故毋須藉由葉面積測定器，利用葉長及葉寬，即可有效地估算出芋之葉面積大小。而且檳榔心芋的葉尖至葉基之最大葉長與葉尖至葉片裂刻之葉長具有一定的1.21：1之比例關係，因此可任意選擇其中一種的葉長測量值來估算單葉面積，而以後者對非破壞性之分析在取樣過程中較爲簡便。水田栽培檳榔心芋之單葉面積估算公式，可爲指數函數或迴歸方程式，其估算準確度均甚高且相近。其中以 $A=0.68\times L_1\times W$ 或 $A=0.82\times L_2\times W$，其模式中的估算介值最少（僅有一個），且不致因取樣時期不同而異，爲最簡單且實用。

關鍵詞：芋、葉面積、推測模式、葉長、葉寬、非破壞性方法。

測量葉面積是作物生育過程及生理性狀上重要指標之一，一般皆以葉面積測定器將葉面積記錄下來，再應用各種分析方法進行分析，然而，儀器的測定固然方便，可信度亦極高，但是如果考慮到葉片連續生長的變化，如要將葉片剪下，終將無法測定不同生長期之面積變化情形，爲了彌補這項缺憾，於是發展了各項利用葉長和葉寬來推測葉面積的測定方法。如 Milford and Riley（1980）就曾利用方程式推測9種甜菜品種的葉片在定溫下生長的速率來配合廣義的對數方程式（generalised logistic equation），並配合葉面積之估算式，藉以評估作物生長的介量。另一種較爲簡易的方式是迴歸方程式的應用，Acharya 等（1984）探討綠豆的8個親本和21個第一代雜種（F_1）之葉片大小和種子大小間的相關，以及種子遺傳變方的成分和初生葉片大小特性間的關係，其主要目的在探討綠豆葉片的長×寬和初生葉片面積的相關性，結果得到預測初生葉片面積的迴歸方程式，顯示出綠豆之初生葉片面積可以間接從葉片的長和寬求出。更簡單的葉面積估算公式，甚至利用葉長及葉寬之乘積僅乘上某個常數即可，例如 Palaniswamy and Gomez（1974）求出水稻的葉面積在乾燥及潮濕季節分別爲其葉長及葉寬乘積之0.73與0.75倍。其他國外學者亦曾針對不同的作物以各種不同的方法來估算葉面積，包括棉花（Ashley *et al.*, 1963）、食用美人蕉（Kato *et al.*, 1989）、玉米（Francis *et al.*, 1969；Pearce *et al.*, 1975；Daughtry and Hollinger, 1984）、花生（Ma *et al.*, 1992）、珍珠粟（Payne *et al.*, 1991）、　高粱（Stickler *et al.*, 1961；Krishnamurthy *et al.*, 1974）、　大豆（

1. 臺灣省農業試驗所　研究報告第 1667 號。
2. 本所農場管理室助理與副研究員兼主任。臺灣省　臺中縣　霧峰鄉。
3. 本所農藝系助理與副研究員。臺灣省　臺中縣　霧峰鄉。

Wiersma and Bailey, 1975）、向日葵（Schneiter, 1978）、芋（Shih and Snyder, 1984）等作物，藉以探研各種作物之光合作用、呼吸作用以至能量之效率等相關性問題。國內學者亦曾就玉米品種臺農351號探討其單葉面積與全株葉面積之簡易估算方法，結果以測量第八葉之葉長及葉寬，取其乘積再以估算單葉面積之介值0.76估算出第八葉之面積，再乘以估算全株葉面積之介值9.27，即可很準確地估出全株葉面積（蕭及劉，1986）。

芋屬天南星科多年生宿根性球莖植物，學名 *Colocasia esculenta* (L.) Schott，爲本省古老民食，及傳統健康食品，其養份價值高，富含高分子澱粉（高纖維）、礦物質及維生素，用途廣泛，可供作主食或副食、製粉、乾糧及食品加工原料等之用。近年來省內需求量年有增加，成爲臺灣重要夏季蔬菜，又爲山地居民之重要糧食；同時栽培簡單而省工，適應性廣，爲推廣精緻農業的最佳作物。其品種甚多，而以檳榔心芋是臺灣目前主要栽培品種，佔栽培面積的最大部份，在日本市場稱爲臺灣芋，栽培形式可爲旱田或水田栽培。本省栽芋歷史已久，但目前有關芋作物之基礎研究，國內報告甚少，至於如何確實、迅速地測量葉面積的方法，目前也僅有國外學者 Shin and Snyder（1984）就 *Colocasia esculenta* (L.) Schott 之芋品種，求出其單葉面積的估算式爲最大葉長與葉寬之乘積再乘以估算介值0.785，但此模式在不同生長期、不同品種或不同試驗地點是否仍然適用，因未有進一步之探討而尚不可得知。因此，本研究之主要目的在探討臺灣本地栽培種檳榔心芋於水田栽培時之單葉面積的簡易估算方法，藉不同取樣時期的葉長及葉寬之測量，以尋找出一套迅速、省時省工、簡單、精確且適用於整個生育期之簡易方式來估算葉面積；又鑑於芋葉之葉片呈楯狀（peltate），其葉緣有一裂刻（lobe），在進行非破壞取樣時，因葉片仍留在植株上，測量葉片之最大長度時，係取穿過兩側葉基與葉尖到葉片裂刻之兩條直線的垂直交點，頗爲費時不便，必須多次測量始能克服技術上的困難，因此往往一不小心就會對葉片造成傷害，而影響了葉片非破壞性之分析工作，亟需尋找另一簡便易行之方式以替代，故本研究在除了考慮最大葉長以外，亦同時嘗試以葉尖至葉片裂刻之長度爲另一種葉長介量，並比較兩種方法間的差異性。

材料及方法

㈠試驗材料之栽培及調查

試驗材料爲檳榔心芋，於1991年（民國八十年）秋作在本所試驗田間進行，以水田栽培形式種植，整地與種植水稻一樣，先將田面充分灌水，然後以耕耘機耕犁、耙平，使本田呈水平狀態，隔天種植。行株距70×30公分，每行30株，共15行。肥料施用以每公頃施用氮素700公斤、磷酐200公斤及鉀素600公斤，均分於整地及前六個月內施完。芋苗成活後，芋田保持淺水3至5公分，以後隨植株生長水位漸次加深至10公分左右，後期田間保持濕潤狀態。生長期間雜草之控制，以種植後1至3天，每公頃均施5％丁基拉草粒劑30公斤，並保持3至5公分淺水3天，種植後一個月再以同量施用一次。生育期間於3個月及5個月各剷除子芋一次，並適時加以45％三苯醋錫可濕性粉劑防治福壽螺，每公頃每次施藥量0.6至1.2公斤，及噴施45％一品松乳劑防治捲葉蟲及蚜蟲，每公頃每次施藥量1.2至1.5公升，稀釋倍數1000倍。自1991年10月26日移植當天，之後於生長期間每隔21天，自田間以破壞性取樣逢機取出10株芋植株，至1992年6月15日收穫爲止，共調查12次，依葉序由外向內利用葉面積測量儀（LI-COR Model LI-3000）測量各不同葉位之葉面積，並以直尺測定全株各葉之長度及最大寬度（W）。其中葉片長度之測量，以兩種方法進行比較，一爲量度沿著中肋由葉尖至葉基之最大長度（L_1），二爲量度葉尖至葉片裂刻之長度（L_2），如圖1所示。

㈡統計分析方法

以葉長及葉寬估算單葉面積的方法，所用以測試的公式有兩類，分別爲指數函數（exponential function）及迴歸方程式（regression equation）。其一般式如下：

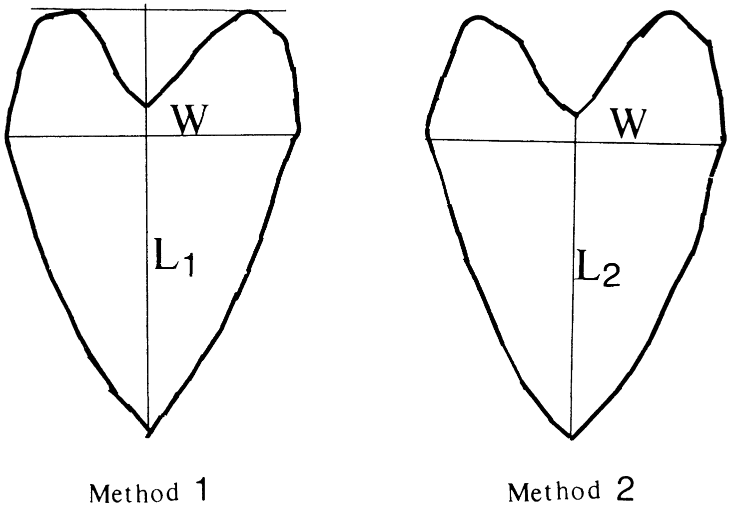

圖1. 測量芋葉長及葉寬之位置。
L_1：沿著中肋由葉尖至葉基之最大長度；
L_2：葉尖至葉片裂刻之葉長；
W：最大葉寬。

Fig. 1. Diagram of taro leaf showing positions of length (L_1, L_2) and width (W) measurements.
L_1: maximum length from lamina tip to lamina base along the mid-rib;
L_2: length from lamina tip to lamina lobe;
W: maximum width of lamina.

(1)指數函數 $A=k\times L^a\times W^b$

式中 k 為常數項，a,b 為指數項，A 為葉面積，L 為葉長介量（L_1 或 L_2），W 為葉寬介量。此式即相當於將所有變數先經對數（log）轉換後所建立的迴歸方程式，即

$$\log A=\log k+a\log L+b\log W$$

。當a＝b＝1時，可進一步簡化公式為

$$A=k\times(L\times W)$$

即葉面積為葉長及葉寬之乘積再乘以一個常數。

(2)迴歸方程式 $A=a+b\times L\times W$

式中 a 為常數項（截距），b 為迴歸係數估值（斜率），A, L, W 的定義同前述。

估算式之配合滿意程度以 R^2（決定係數，coefficient of determination）及 CV（變異係數，coefficient of variation）表示。

本研究之各項統計分析工作均依據 SAS（Statistical Analysis System, 1988）套裝統計分析軟體，以 IBM 相容個人電腦建檔及運算。

結　果

(一)芋葉片性狀之生長變化

自移植當天起至收穫結束，每隔21天（3週）逢機取樣10株，調查檳榔心芋各生長時期單株平均葉數（LN）、單葉面積（A）、葉尖至葉基之最大葉長（L_1）、葉尖至葉片裂刻之長度（L_2）及最大葉寬（W），結果列如表1。其生長過程中葉數及葉面積的生長變化情形如圖2所示，本試驗取一

葉齡種芋移植後，植株葉數即快速增加，在第22天之平均葉數爲3.3片，第43天時爲4.3片，之後增加速度緩慢，至第127天時葉數最多，平均5.6片，接著由於球莖加速膨大，葉數隨即減少；單葉面積的生長趨勢與葉數恰好相反，在生長初期增加平緩，自移植後127天葉數最多時，單葉面積才開始急速擴展，到第211天之採收適期可達最大，平均1323.9㎠，爾後即因近收穫末期，植株逐漸老化枯萎，葉面積便不再增大而逐漸縮小。

葉長及葉寬於整個生長過程中伸展及縮減的變化相當一致，如圖 3 所示 ，表示芋葉的形狀於整個生長過程中大致保持固定。從而由表 2 結果得知，檳榔心芋之最大葉長（L_1）對葉寬（W）的比例，各生長階段約在1.31～1.40之間變動，平均1.36；葉尖至葉片裂刻之長度（L_2）對葉寬（W）的比例，約在1.09～1.15之間，平均1.12。按此生長期間保持固定葉形爲芋作物的植物特性，但品種不同，其葉片長寬度的比例也可能不盡相同。再比較葉長、葉寬及單葉面積的生長趨勢，則完全相同（圖 2 ，3），顯然葉長、葉寬及單葉面積之間存在有極顯著的正相關關係，亦即芋作物之單葉面積係共同決定於葉長及葉寬。因此利用葉長及葉寬，應可間接而準確地估算出芋葉面積的大小， 而毋須藉由儀器測定方法才能得知。以葉長及葉寬估計葉面積的方法，不但快速簡便 ，也可避免破壞性取樣所造成的困擾。

表1. 芋不同取樣時期之單株葉數（LN）、單葉面積（A）、兩種葉長介量（L_1，L_2）及葉寬（W）的平均值與標準差

Table 1. Mean values and standard deviations of leaf number (LN), individual leaf area (A), two leaf length measurements (L_1, L_2), and leaf width (W) of taro at the different sampling times

Days after transplanting	LN	A (㎠)	L_1 (㎝)	L_2 (㎝)	W (㎝)
1	1.0±0.0	64.5± 10.1	12.3±1.4	10.2±1.2	9.0±0.9
22	3.3±0.5	90.6± 32.7	12.7±2.0	10.5±1.6	9.7±1.7
43	4.3±0.7	167.7± 51.5	17.9±3.0	14.8±2.5	13.3±2.0
64	4.4±1.2	222.0± 75.8	20.4±3.4	16.8±2.9	15.2±2.6
85	4.5±0.7	234.3± 81.8	21.4±3.7	17.7±3.1	15.6±2.8
106	5.0±0.5	302.8± 86.5	23.9±3.3	19.8±2.8	17.3±2.4
127	5.6±0.5	402.4±111.4	27.8±3.9	23.0±3.1	20.5±3.0
148	5.1±0.7	650.8±221.5	34.8±5.3	28.7±4.3	25.9±4.8
169	4.3±0.5	985.1±262.5	43.2±5.4	35.5±4.5	31.8±4.3
190	3.5±0.5	1096.4±298.4	45.9±5.2	37.8±4.3	33.5±4.0
211	2.8±0.8	1323.9±286.3	50.9±5.8	41.8±4.8	38.4±4.8
232	3.2±0.8	1106.4±353.7	46.5±7.0	38.3±5.8	33.6±6.2

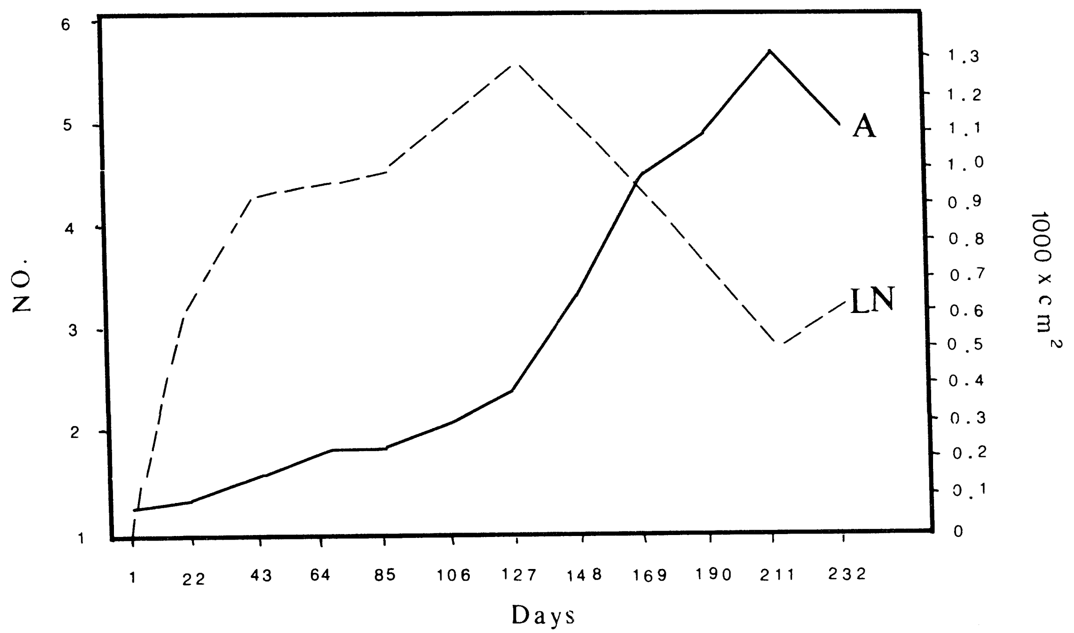

圖2. 芋單株葉數（LN）及單葉面積（A）之生長變化。

Fig. 2. Changes of leaf number (LN) and individual leaf area (A) during the growth period of taro.

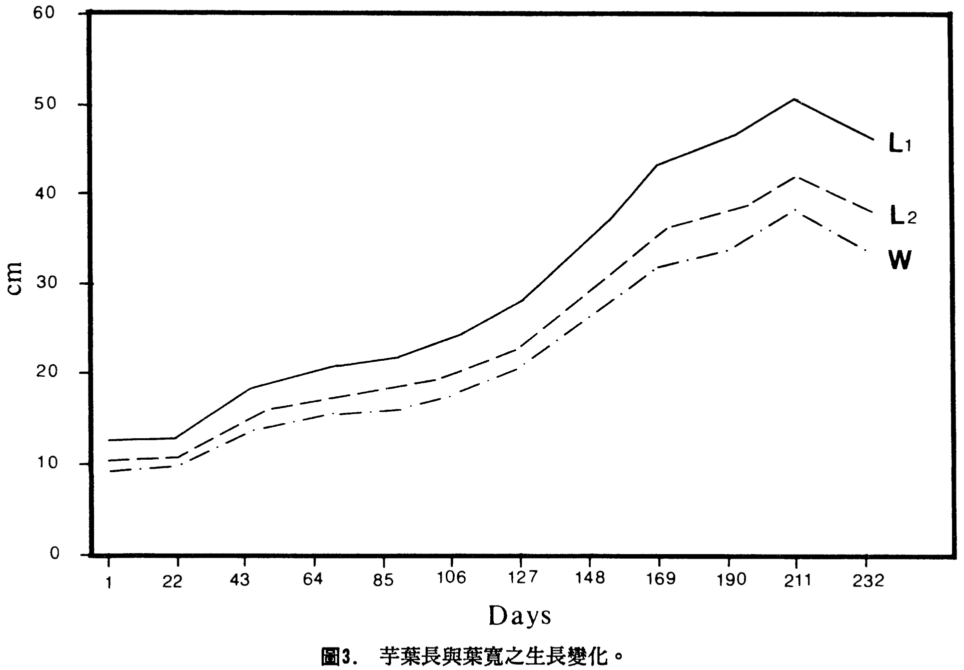

圖3. 芋葉長與葉寬之生長變化。

L_1，L_2 及 W 之定義如圖1。

Fig. 3. Changes of leaf lengths (L_1 and L_2) and leaf width (W) during the growth period of taro.

Definitions of L_1, L_2 and W given in Figure 1.

(二)利用葉長與葉寬推測單葉面積的估算式

本試驗材料檳榔心芋的葉尖至葉基之最大葉長（L_1）與葉尖至葉片裂刻之葉長（L_2）間的比值，則由生長初期的1.21，到第169天起之生長後期略增爲1.22，平均約爲1.21（表2），即大致呈一定的1.21：1之比例，因此利用葉長及葉寬來估算葉面積，可任意選擇其中一種的葉長測量值。有鑑於一般測量作物葉片多採以最大葉長及葉寬，因此本研究首先以最大葉長及葉寬來探明檳榔心芋單葉面積的估算公式；倘改以葉尖至葉片裂刻之葉長來取代最大葉長，則兩者間的差異僅在估算公式之估算介值恰好呈一定的1.21之倍數關係。

表2. 芋不同取樣時期之葉長與葉寬間的比例關係

Table 2. Ratios of leaf length and leaf width of taro at the different sampling times

Days after transplanting	L_1/W	L_2/W	L_1/L_2
1	1.37±0.08	1.13±0.07	1.206±0.004
22	1.31±0.08	1.09±0.07	1.206±0.004
43	1.35±0.08	1.11±0.07	1.211±0.003
64	1.34±0.10	1.11±0.08	1.210±0.005
85	1.38±0.08	1.14±0.06	1.209±0.005
106	1.38±0.09	1.15±0.08	1.207±0.005
127	1.36±0.07	1.13±0.06	1.208±0.007
148	1.36±0.08	1.12±0.06	1.215±0.006
169	1.36±0.05	1.12±0.04	1.216±0.001
190	1.37±0.05	1.13±0.04	1.216±0.001
211	1.33±0.05	1.09±0.04	1.216±0.001
232	1.40±0.09	1.15±0.07	1.217±0.001
Mean	1.36±0.08	1.12±0.07	1.212±0.006

所用以測試的公式有兩類，分別爲指數函數及迴歸方程式。首先考慮指數函數中兩底數 L 及 W 之指數值可能不等的情況，即估算公式爲 $A=k\times L^a\times W^b$，此式即相當於將 A, L, W 先經對數（log）轉換後所建立的迴歸方程式，由表3之結果得知，除了移植當天及自第190天起之生長後期以外，各取樣時期之兩指數值 a, b 皆接近於1，常數 k 值則大致在0.52～0.74之間，用以檢驗模式適合度的決定係數 R^2 值均在0.93以上，CV值亦不超過1.5，顯示檳榔心芋在生長過程中，如不考慮移植當天及生長後期，以簡化模式 $A=k\times(L\times W)^a$ 建立單葉面積之估算公式，可能適當；如不計較生長階段上之差異性，則可利用最大葉長及葉寬建立水田栽培檳榔心芋的單葉面積指數函數估算式爲

$$A=0.72\times L_1^{0.8}\times W^{1.2} \qquad R^2=0.993$$

。倘進而考慮 $A=k\times(L\times W)^a$ 之單葉面積估算公式，結果如表4所列，除了移植當天以外，各取樣時期的指數 a 值均極接近於1，R^2 都高於0.93以上，CV值不超過1.7，顯然利用最大葉長及葉寬來估算檳榔心芋單葉面積的方法，各時期可簡單地以 $A=k\times L\times W$ 之函數關係表示，其常數項 k 值在不同時期稍有差異，約在0.34～0.81間變動，平均爲0.68，即水田栽培檳榔心芋的單葉面積爲其最大葉長及葉寬之乘積再乘以一個介值，即

$$A=0.68\times L_1\times W \qquad R^2=0.993$$

表3. 芋不同取樣時期下利用最大葉長與葉寬推測單葉面積之 $A=k\times L^a\times W^b$ 估算式的估值

Table 3. Estimates of leaf area parameters from the equation $A=k\times L^a\times W^b$ using maximum leaf length and width of taro at the different sampling times

Days after transplanting	k	SE (k)	a	SE (a)	b	SE (b)	R^2	CV
1	2.25	0.88	0.10	0.35	1.42	0.43	0.866	1.56
22	0.74	0.07	0.76	0.10	1.26	0.09	0.991	0.71
43	0.59	0.07	0.74	0.13	1.34	0.16	0.978	1.02
64	0.63	0.12	0.64	0.15	1.44	0.15	0.952	1.50
85	0.66	0.10	0.76	0.16	1.27	0.16	0.976	1.07
106	0.52	0.11	0.77	0.16	1.37	0.16	0.943	1.34
127	0.71	0.12	1.22	0.14	0.75	0.14	0.962	0.93
148	0.70	0.21	1.12	0.29	0.87	0.24	0.935	1.36
169	0.70	0.22	0.81	0.33	1.21	0.30	0.935	1.06
190	0.50	0.02	0.30	0.30	1.75	0.28	0.952	0.77
211	1.20	0.01	0.45	0.30	1.44	0.26	0.962	0.73
232	0.72	0.27	0.43	0.36	1.61	0.28	0.979	0.89
Mean	0.72	0.02	0.76	0.06	1.24	0.06	0.993	1.23

表4. 芋不同取樣時期下利用最大葉長與葉寬推測單葉面積之 $A=k\times(L\times W)^a$ 估算式的估值

Table 4. Estimates of leaf area parameters from the equation $A=k\times(L\times W)^a$ using maximum leaf length and width of taro at the different sampling times

Days after transplanting	k	SE (k)	a	SE (a)	R^2	CV
1	2.63	1.12	0.68	0.12	0.806	1.76
22	0.66	0.06	1.02	0.02	0.989	0.77
43	0.62	0.08	1.02	0.03	0.975	1.05
64	0.56	0.12	1.04	0.04	0.943	1.61
85	0.60	0.08	1.02	0.03	0.974	1.09
106	0.47	0.10	1.07	0.04	0.939	1.38
127	0.79	0.13	0.98	0.03	0.960	0.95
148	0.80	0.20	0.98	0.04	0.934	1.35
169	0.61	0.16	1.02	0.04	0.934	1.05
190	0.50	0.14	1.05	0.05	0.942	0.83
211	0.81	0.21	0.97	0.04	0.957	0.76
232	0.34	0.07	1.09	0.03	0.977	0.93
Mean	0.68	0.01	1.00	0.00	0.993	1.25

。如直接以單葉面積測量值對其最大葉長及葉寬之乘積作迴歸（亦即事先不經任何轉換）來考慮估算公式之建立，結果如表5所列，除了移植當天以外，各時期之單葉面積也能以簡單迴歸模式配合良好，R^2 都在0.92以上，CV 值均在9.0之內，迴歸係數估值在0.65至0.77之間，變異不大，但常數項則因取樣時期不同而差異頗大，變域在－96.03～43.15之間；倘不計較生長階段上之差異性，生育全期之迴歸方程式可表示爲

$$A=4.06+0.69\times L_1\times W \qquad R^2=0.988$$

表5. 芋不同取樣時期下利用最大葉長與葉寬推測單葉面積之A＝a＋b×L×W 估算式的估值

Table 5. Estimates of leaf area parameters from the equation A=a+b×L×W using maximum leaf length and width of taro at the different sampling times

Days after transplanting	a	SE (a)	b	SE (b)	R^2	CV
1	19.96	7.22	0.40	0.06	0.832	6.85
22	−4.89	1.79	0.76	0.01	0.990	3.60
43	−2.65	4.31	0.70	0.02	0.976	4.77
64	−2.74	7.31	0.71	0.02	0.961	6.79
85	−4.08	4.54	0.70	0.01	0.986	4.15
106	−14.03	10.44	0.75	0.02	0.954	6.23
127	12.91	11.88	0.67	0.02	0.956	5.90
148	16.93	25.08	0.69	0.03	0.935	8.74
169	1.23	46.75	0.71	0.03	0.920	7.63
190	−96.03	54.89	0.77	0.03	0.940	6.88
211	43.15	63.62	0.65	0.03	0.942	5.30
232	−33.14	48.66	0.71	0.03	0.952	7.11
Mean	4.06	3.55	0.69	0.00	0.988	8.92

由本研究前述結果發現，檳榔心芋的葉尖至葉基之長度（L_1）爲葉片裂刻至葉尖之長度（L_2）的1.21倍左右（表2），故另可採以後者與最大葉寬之乘積來估算單葉面積，分別爲

$$A=0.83\times L_2^{0.8}\times W^{1.2} \qquad R^2=0.993$$

$$A=0.82\times L_2\times W \qquad R^2=0.993$$

$$A=2.53+0.84\times L_2\times W \qquad R^2=0.988$$

。在以非破壞取樣於田間進行芋作物葉片之最大葉長的測量時，由於葉片仍留在植株，穿過兩側葉基與葉尖到葉片裂刻之兩條直線的垂直交點，較難確實掌握，必須多次測量始能克服技術上的困難，如此往往一不小心就會對葉片造成傷害，而影響了葉片非破壞性之分析工作，因此測量葉尖至葉片裂刻之長度，可更爲簡便而實用。

㈢葉面積估算式之預測準確度

爲檢測所建立之檳榔心芋葉面積估算式的預測能力，本試驗進而從以相同慣行法水田栽培的另外兩塊不同田間內，再逢機取出各50片大小不同的檳榔心芋葉片，利用其葉長及葉寬，配合以上六種模式，探討預測葉面積與實際葉面積之間的差異，其結果如表6所示。結果得知，無論採以任何一種葉長測量值（L_1 及 L_2），利用指數函數或迴歸方程式，所預測的葉面積皆頗接近於實際測量的葉面積，其離差甚小，以50片總葉面積而言，誤差率（Percentage of deviation）均約在1～2%左右，有時更低於1%以下，而平均估算一片芋葉之葉面積的誤差率（Mean percentage of deviation）則僅

在5～6％之間。此與統計上一般以1％及5％爲顯著水準之第一型錯誤率（type I error）相吻合，顯示該六種芋單葉面積之估算模式的預測能力，頗爲相近，且其誤差率在可接受的程度之內。由於最適模式的選擇，不但須要求準確性高，也希望估算式中所含估算介值能最少，因此其中以葉長與葉寬之乘積直接乘上一個常數，所含估算介值最少，僅有一個，應最具有實用之價值。

表6. 由再取樣的50片芋葉樣本比較各種單葉面積之估算式的準確度

Table 6. Comparison of accuracy of equations in estimating individual leaf area of 50 leaves of taro from further sampling

Model	Total area measured (cm²)	Total area predicted (cm²)	Dev. (%)[a]	Mean dev. (cm²)[b]	Mean dev. (%)[c]
Sample I					
$A=0.72\times L_1^{0.8}\times W^{1.2}$	30844.8	30383.2	1.50	33.47	5.77
$A=0.68\times L_1\times W$	30844.8	30472.3	1.21	33.73	5.75
$A=4.06+0.69\times L_1\times W$	30844.8	31123.5	0.90	30.82	5.17
$A=0.83\times L_2^{0.8}\times W^{1.2}$	30844.8	29992.1	2.76	35.84	6.28
$A=0.82\times L_2\times W$	30844.8	30286.9	1.87	34.29	5.81
$A=2.53+0.84\times L_2\times W$	30844.8	31133.6	0.94	30.84	5.08
Sample II					
$A=0.72\times L_1^{0.8}\times W^{1.2}$	31287.7	31264.5	0.07	30.62	5.51
$A=0.68\times L_1\times W$	31287.7	31342.1	0.17	32.16	5.80
$A=4.06+0.69\times L_1\times W$	31287.7	32006.0	2.30	31.86	5.43
$A=0.83\times L_2^{0.8}\times W^{1.2}$	31287.7	30854.7	1.38	31.16	5.77
$A=0.82\times L_2\times W$	31287.7	31123.3	0.53	32.18	5.86
$A=2.53+0.84\times L_2\times W$	31287.7	32008.9	2.31	31.87	5.41

[a]: Percentage of deviation=
|total measured area－total predicted area|×100／total measured area.

[b]: Mean deviation=
$(\sum_{i=1}^{n}|\text{measured area}_i-\text{predicted area}_i|)/n.$

[c]: Mean percentage of deviation=
$(\sum_{i=1}^{n}|\text{measured area}_i-\text{predicted area}_i|\times100/\text{measured area}_i)/n.$

討　　論

綜合以上結果可知，由於芋葉的葉形在整個生長過程中大致維持固定，故利用葉長及葉寬，即可簡單而迅速地估算出芋之葉面積大小。由於檳榔心芋的葉基至葉尖之最大葉長與葉尖至葉片裂刻之葉長具有一定的1.21：1之比例關係，因此可任意選擇其中一種的葉長測量值來估算單葉面積，而以後者對非破壞性之分析在取樣過程中較爲簡便。

水田栽培檳榔心芋單葉面積之估算公式可爲指數函數或迴歸方程式，其估算準確度均相差無幾。就利用葉長與葉寬推算單葉面積而言，倘若採用指數不等的指數函數關係式，雖然模式配合度（R^2）最高，但估算式中之介值較多（常數項及兩個指數估計值）且會隨著生長階段不同而異，利用效率大爲降低；如以簡單迴歸模式表示，亦可配合良好，且迴歸係數估值於各取樣時期變異不大，但迴歸式中的常數項常因時期不同而變動，使用上較爲不便；其中以葉長及葉寬之乘積直接乘以某個常數值

，最爲簡單，且各時期的變異也不大（不計移植當天），實用上頗具價值，值得採用。結果顯示，利用最大葉長與最大葉寬之乘積再乘以估算介值0.68，或者以葉尖至葉片裂刻之葉長與最大葉寬之乘積再乘以0.82，即可準確地估算出檳榔心芋於水田栽培下的單葉面積。然本研究係以檳榔心芋爲試驗材料，所獲得之各個估算介值並不一定適用於所有的試驗地點或品種。如 Shin and Snyder (1984) 以最大葉長與葉寬估算不同芋品種於水田栽培時之單葉面積之估算介值爲0.785，與本試驗所獲結果之0.68，仍有差異；唯本試驗既以臺灣本地栽培種爲材料，所得之結果自將更適合於本地研究者所採用。而直接利用葉長和葉寬推測葉面積的方法，可無須傷到葉片即可進行測量，所以一般若不需算出精確之葉面積時，此法經常被採用，尤其是運用到觀察不同時期之葉面積的連續變化。由於葉長與葉寬之間仍有一定的比例關係，而隨著生長時間不同，其比值變異也不太大（表2及圖3），因此如在不要求太高準確度的情形下，甚至可直接用直尺實際測量葉寬即可，然後以其倍數關係推算出葉長介量，再以葉長與葉寬推測單葉面積，此更爲省工省時，但是經過兩次的估算步驟，誤差率難免會較高。

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A simple method for estimating leaf area in wetland taro (*Colocasia esculenta* (L.) Schott)[1]

L. F. Chan[2], C. T. Lu[3], H. Y. Lu[3] and C. H. Lai[2]

Summary

This study was made to develop an accurate, simple and rapid method for estimating individual leaf area of wetland taro [*Colocasia esculenta* (L.) Schott] under different growth periods in Taiwan. The experiment was conducted in the fall crop of 1991 at Taiwan Agricultural Research Institute. A total of 10 plants was randomly sampled at 21-day intervals starting at transplanting and ending at harvest. The area (A), length from lamina tip to lamina base along the mid-rib (L_1), length from lamina tip to lamina lobe (L_2), maximum width of lamina (W) of each leaf were measured.

Results indicated that leaf length and width were available for estimation of leaf area without leaf area meter, because the leaf shape of taro almost kept constant during the whole periods of plant growth. Since there was a proportion relationship of 1.21 : 1 between L_1 and L_2, either of them can be defined as the length measurement. However, L_2 facilitates nondestructive measurement of leaf length. The exponential functions and regression equations were all best fitted to estimate leaf area in wetland taro, and had the similar predictive ability. The formulae of $A=0.68\times L_1\times W$ and $A=0.82\times L_2\times W$ were the most easy and useful methods to estimate the leaf area of wetland taro, because the models possessed the least number of estimating factors (only one), and performed well for different growth periods.

Key words : Taro, Leaf area, Predictive model, Leaf length, Leaf width, Nondestructive method.

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1. Contribution No. 1667 from Taiwan Agricultural Research Institute.

2. Research Assistant and Agronomist, Office of Farm Management, TARI, Wufeng, Taichung Hsien, Taiwan 413, ROC.

3. Research Assistant and Statistician, Department of Agronomy, TARI, Wufeng, Taichung Hsien Taiwan 413, ROC.

Jour. Agric. Res. China (中華農業研究) 42(2)：173~186 (1993)

Growth and yield respones of maize (*Zea mays* L.) to soil water deficits.
II. Effects of water deficit timing and strength[1]

Chwen-Ming Yang[2], Ming-Jen Fan and Wei-Min Hsiang

Abstract: Water is a major limiting factor on maize production in Taiwan. It is very important, therefore, to study the relations of soil moisture stress and maize (*Zea mays* L.) yield under local conditions. This field work was conducted on the experimental farm of Taiwan Agricultural Research Insitiute (TARI) at Wufeng, Taiwan to evaluate the relative effects of water deficit timing and strength on the growth and yield of maize, cultivar Tainung No. 1. Water stress was imposed by the withholding of irrigation during reproductive growth phase (fall crop 1991) and vegtative growth phase (spring crop 1992), respectively, to cause soil water potentials to the range from $-\frac{1}{3}$ (control) to -10 bars. It was shown that leaf number per plant was not significantly affected by water stress in both seasons, whereas leaf area per plant was reduced when soil water potential lowered to -5 bars in the fall crop of 1991 and -8 bars in the spring crop of 1992. As indicated by plant height measured at the 50% silking, a 13-day period of water deficit to -8 bars in the vegetative growth phase of spring crop influenced plant growth in the long run. The heading and the silking dates were not dramatically changed by water deficits in both crops. But more than 10% reduction of plant weight was recorded as soil water potential decreased to below -5 bars in the reproductive phase. Ear weight and kernel yield were decreased by water stress below -2.5 bars in both crop seasons. Kernel yield was reduced to 60 and 80% of the control at -10 and -8 bars in fall crop and spring crop, respectively, which mainly associated with a lower kernel weight. It is suggested that soil water potential can be employed on predicting maize production by water deficit and kernel yield reduction depends on severity of soil water stress.

Key words: Growth, Maize, Soil water deficit, Strength, Timing, Yieid.

INTRODUCTION

Maize is ofter grown in areas of subtropical rainfall and limited irrigation in Taiwan. As energy costs and the demand of water by industry and home usage go up, timely irrigation before the occurrence of crop injury by water stress becomes an important issue for cultivated lands where water resources are limiting.

1. Contribution No. 1668 from Taiwan Agricultural Research Institute (TARI). This work was supported by Council of Agriculture under grant 81-Nung Chien-2.1-Forest-28-2(5).

2. Respectively, Agronomist, Department of Agronomy, Research Fellow, Crop Genetic Resources Laboratory, and Assistant Soil Scientist, Department of Agricultural Chemistry, TARI, Wufeng, Taichung Taiwan 413, Republic of China.

Maize is known liable to moisture stress. An ample amount of information is available with regard to the effects of water deficit on maize water relations and the related metabolic processes and morphological variations (Acevedo *et al.,* 1971; Beadle *et al.,* 1973; Boyer, 1970a; Hsiao, 1973; Lawlor, 1978; McPherson and Boyer, 1988; Ouatter *et al.,* 1987a, 1987b; Turner and Begg, 1974; Westgate and Boyer, 1985). It is less clear, yet important, on quantitative relationship of water stress level and yield of maize and the effect of stress timing.

Maize has distinct phases of plant development (Johnson and Tanner, 1972; Ritchie *et al.,* 1986), however, there remains uncertainty about the developmental sensitivity to the adverse effects of water deficit, i. e., their sensitivity to water deficits and ultimate effects of water stress of kernel yield. Substantial yield losses have been reported when water deficits occur during vegetative growth (Denmead and Shaw, 1960; Lorens *et al.,* 1987; Miller and Duley, 1925). Classen and Shaw (1970) reported that from one week prior to silking to two weeks after silking is the greatest sensitive period of kernel yield to water stress. Grant *et al.* (1989) further indicated that kernel number is especially sensitive to moisture stress during the seven days period after silking, whereas kernel weight is reduced during the kernel filling period. Moss and Downey (1971) suggested that stress prior to silking causing the shortage of carbohydrate results in reduced kernel number. Such information is required for water management and cost reduction planning in maize production in local conditions.

Under the competitive field environment where dry conditions of varying duration and intensity may occur frequently during the growing season, a better picture of the quantitative relationship between corn yield and the level and timing of water deficit would be helpful in establishing of strategies for maize-irrigation management. Experiments were therefore made to study longer term effect of maize growth and yield subjected to a period of soil water deficit during vegetative or reproductive phase. The relative effects of water stress on the agronomic traits associated with yield reductions were also evaluated.

MATERIALS AND METHODS

Two separate experiments were conducted in the fall crop of 1991 and the spring crop of 1992, respectively, to study the effects of water deficit imposed at different growth phases on maize growth and yield. Maize cultivar 'Tainung No. 1' was sown 10 August 1991 on a silt loam (mixed, nonacid, hyperthermic, Fluvaquentic Dystrochrept) at the experimental farm of TARI. In 1992, the hybrid was planted on 28 February. The soil contained 22.4% clay, 51.1% silt and 26.5% sand with 1.77% (fall) and 2.23% (spring) organic matter and with pH 6.2 (fall) and 5.6 (spring) in the top 20 cm soil layer. The bulk densities were 1.25 and 1.55 g cm^{-3}, and the soil moisture contents were 27.72 and 28.23% at $-1/3$ bar and 9.25 and 7.79% at -15 bars in the fall and the spring, respectively. Seeds were hand-planted three per hill in 9.0 m north-south rows with 0.25 m in-row and 0.70 m between-row spacings and then thinned to one seedling per hill a week later resulting in a final population of 57,100 plants ha^{-1}. Each experimental plot consisted nine rows with outer two rows as borders.

Restricted by weather conditions, the hybrid was subjected to soil moisture deficits in either reproductive, fall crop 1991, or vegetative, spring crop 1992, phase by withholding irrigation water until the desired levels of water stress were reached. Three water potential ranges, i. e., -2.5, -5.0 and -10.0 bars, were made in fall; whereas -8.0 bars, instead of

-10.0 bars, was attained in spring. Soil water potential was maintained within field capacity (measured by tensiometer), which was based on measured water contents in the root zone profile at 0.20 m depth, in control plots. The gypsum blocks were buried, two for each plot, prior to stress treatments and a predetermined resistance and soil water potential relationship was used to calculate soil water potential in each plot between 1300 to 1400 every day during the treatment periods. In fall crop the stress period was 20 days in duration and imposed from 10 September, which corresponding to one week before tasseling, to 29 September, during early reproductive development. In spring corn plants were exposed to different soil moisture ranges at the time of the eighth to the tenth leaf on the main culm (25 April to 7 May) in vegetative growth phase. Enough water was added by furrow irrigation to the experimental plots when the soil water potential approached the desired value and the plots were irrigated as the optimal irrigation treatment (control) thereafter.

Fertility was maintained with a side-dress applications of commercially available fertilizers (50—70—50 kg ha^{-1}; N-P_2O-K_2O) onto the soil surface at planting. Additional 120 kg ha $^{-1}$ of nitrogen (in the form of ammonium sulfate) was applied with equivalent at 3, 6 and 9 weeks after planting. On sowing, the insecticide carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methyl carbamate, 3% granule, 30 kg ha^{-1}) was applied on soil surface after planting and was again sprayed on the canopy using 40.64% fluid at a rate of 1.2 L ha^{-1} at 5 weeks after planting. Weed control was achieved with hand weeding applied on 4 weeks after planting. The meteorological data were collected from the weather station at TARI experimental farm.

Six plants of each treatments were sampled on 30 September 1991 and on 22 May 1992 to investigate changes of plant height, leaf number, and leaf to different soil moisture levels. Maize height was measured from the soil surface to the highest point of plant. Numers of leaves per plant were counted on leaves with more than 50% area were green. Leaf area was measured on a Li-Cor model LI-3,000 area meter (Li-Cor, Inc., Nebraska, USA). Dry weights of stem and leaf were measured after oven-dried at 80 °C for 72 h. Soil core samples were taken to a depth of 0.20 m and a diameter of 0.20 m from the base of the stem. Roots were collected by washing out soil from sample, oven-dried at 80 °C for 72 h and weighed. Two middle-rows of plants were hand-harvested on 21 October 1991 and 23 June 1992, respectively, to determine ear number, ear length, ear weight, and kernel weight. The latter two parameters were converted to the weight per hectare and yield was determined. The effective plant percentage (EPP) at harvest was calculated by counting the number of plants with ear(s) in each plot relative to the seedling numbers (after thinned to one seedling per hill).

The field layout was a randomized complete-block design (RCBD) with four replications. Analyses of variance and the LSD test were used to determine differences in maize growth parameters and yield between water deficit treatments. Linear regression analyses were performed to determine the relationships between kernel yield and growth parameters and soil water potential in two crop seasons.

RESULTS AND DISCUSSION

Maize hybrid cultivars are often developed in near optimal environment of water availability in Taiwan, still frequently are grown under various levels of soil moisture stress

in field. The study of the response of maize growth and yield to water deficits is therefore needed and valuable in planning irrigation schedule and management programs aimed at conserving water while attaining acceptable maize yield.

The daily mean temperature, irradiance and rainfall during the growing seasons of 1991 and 1992 were shown in Figures 1 and 2, respectively. A distinct climatic pattern was shown, which not only restricted the imposed stress duration and soil water potential (Fit. 3) but governed growth behavior of maize. The accumulated amount of temperature, irradiance and rainfall were 1,919.4 °C, 1,008.3 MJ m^{-2} and 257 mm for fall crop and 2,666.5 °C, 1,304. 2 MJ m^{-2} and 660 mm for spring crop. The climate was wet in spring than in fall.

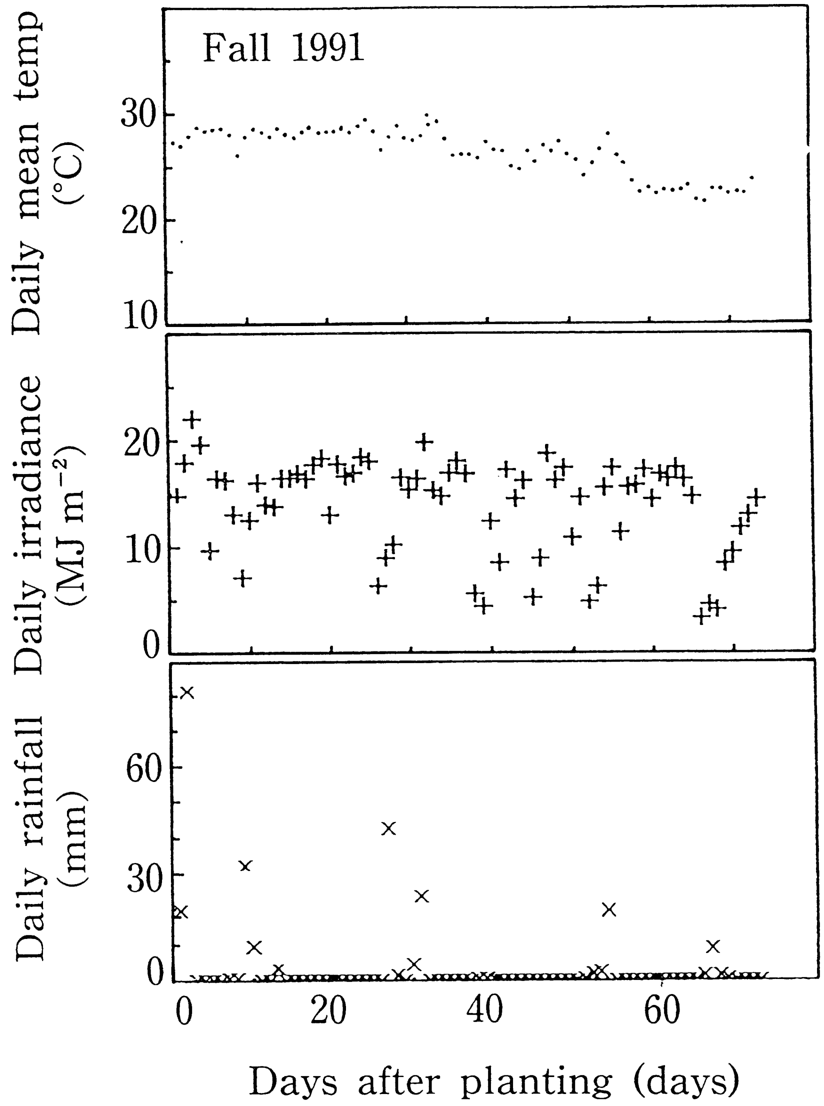

Fig. 1. The daily mean temperature, irradiance and rainfall during the growing season of fall 1991.

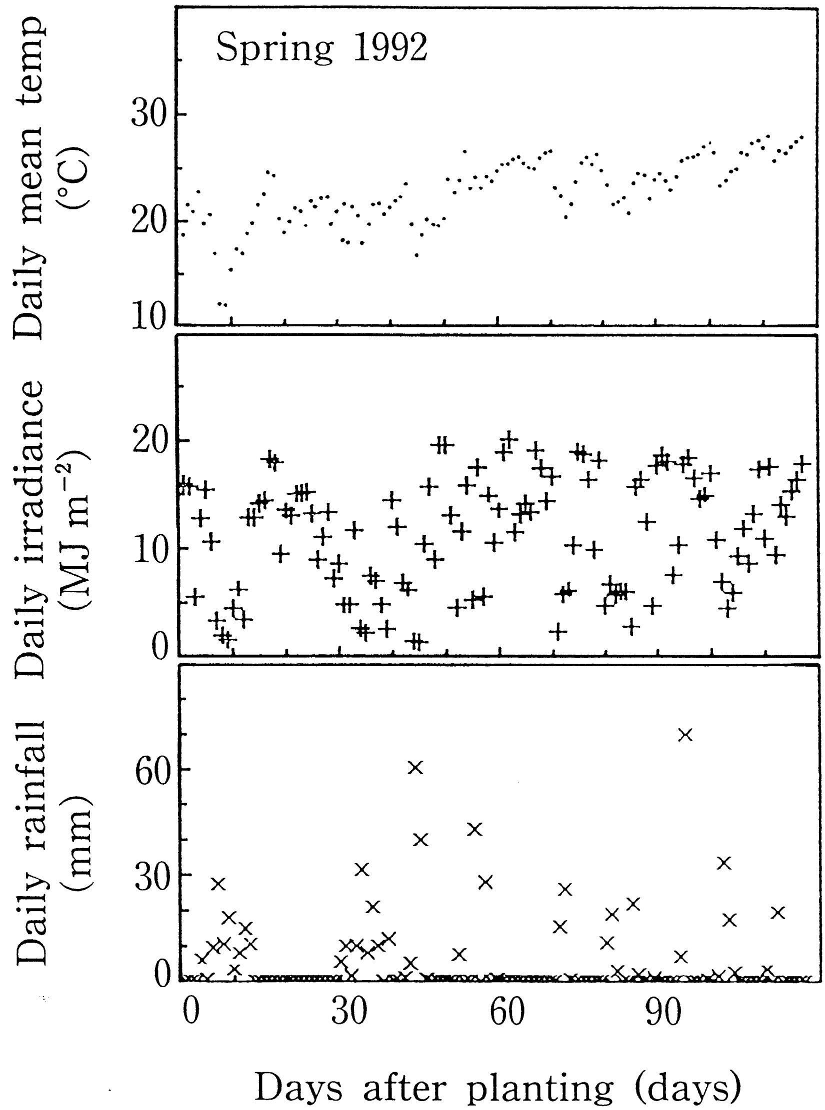

Fig. 2. The daily mean temperature, irradiance and rainfall during the growing season of spring 1992.

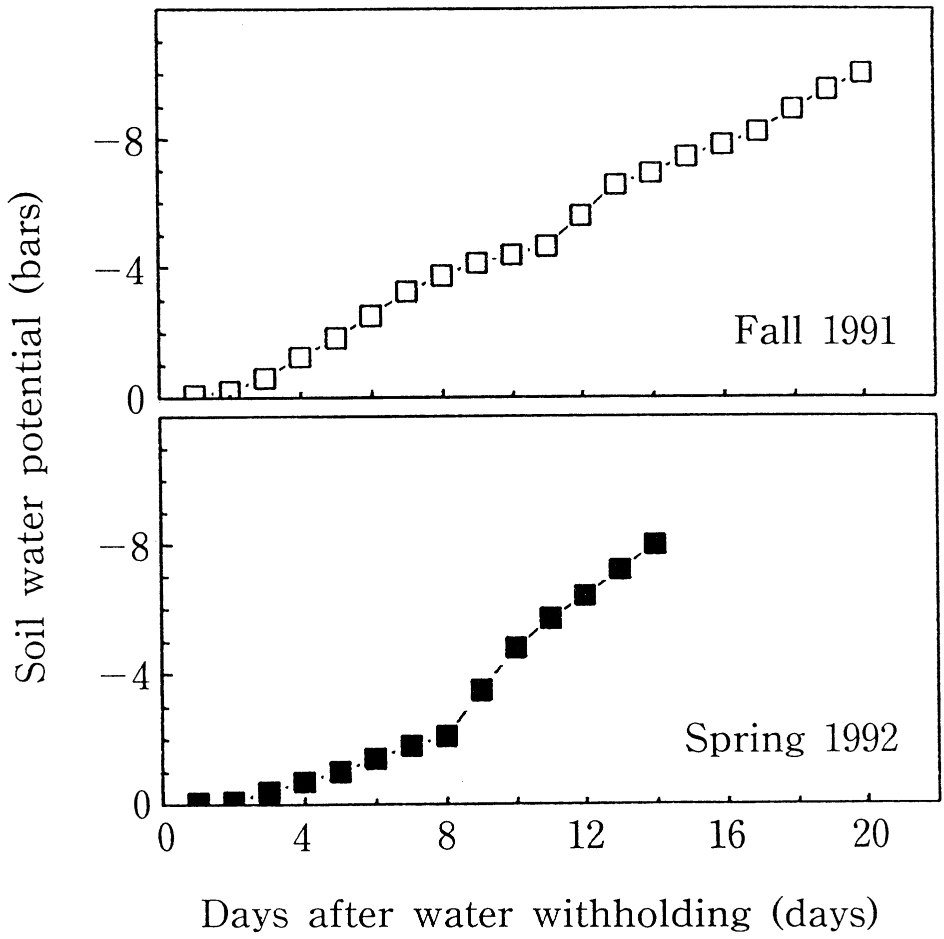

Fig. 3. Changes of soil water potential after water withholding during the treatment periods in fall crop 1991 and spring crop 1992, respectively.

Plant growth in response to different levels of soil water deficit was investigated by measuring growth parameters after stress period, ca. one week after the 50% of silking for the fall season of 1991 and at the 50% of silking for the spring season of 1992. It appeared that plant height was not significantly affected to desiccation during reproductive phase, as vegetative growth was ended, in fall crop, but was reduced at −8.0 bars when stress occurred in the vegetative phase of spring crop (Table 1). Chotena *et al.* (1980) and Classen and Shaw (1970) noted that plant height of maize can be reduced by drought stress. Number of leaves per plant was unchanged by soil water deficits, whereas leaf area was decreased by −5.0 and −8.0 bars of water potential in 1991 and 1992, respectively (Table 1). When soil water potential lowered to −5.0 bars in fall, but not in spring, plant weight declined (Table 2). Leaf and stem dry weights were reduced 16% by water stress when soil water potential reached down to −5.0 and −10.0 bars, respectively. Obviously leaf growth was more sensitive to desiccation than stem growth. Miller and Duley (1925) and Acevedo *et al.* (1971)

also found that leaf growth responds more readily to water stress than other parts of maize plant. Van Volkenburgh and Boyer (1985) showed that proton excretion in wall-loosening events for cell enlargement is inhibited and hence reduces leaf growth rate upon water deficit. Further, a close relationship between leaf growth and soil water potential in maize was concluded by Boyer (1970a) and Michelena and Boyer (1982) in longer term experiments.

Based on the heading and silking dates (Table 3), maize reproductive development did not dramatically influenced by water stress within the test ranges (Table 3). Apparently dry matter accumulation during the growing season control plant development rather than during the drought period. Whereas, Frederick *et al.* (1989) and others (Herrero and Johnson, 1981; Kiesselbach, 1950; Salter and Goode, 1967) reported that the silking and anthesis dates were delayed and grain-filling period was decreased by drought stress in maize when stress initiated from the V7 (Richie *et al.*, 1986) to the R 2 stage.

Table 1. Influence of soil water deficits on growth characters of maize Tainung No. 1 in fall crop of 1991 and spring crop of 1992.

Moisture stress treatment	Plant height	Leaf number	Leaf area
	------------cm------------	No. $plant^{-1}$	cm^2 $plant^{-1}$
Fall 1991*			
Control	225.9	12.3	4,696
− 2.5 bars	219.5	11.6	4,357
− 5.0 bars	216.4	11.7	4,148
−10.0 bars	212.1	11.0	3,839
$LSD_{(0.05)}$	14.7	1.3	408
Spring 1992**			
Control	210.3	10.2	3,393
−2.5 bars	212.2	10.1	3,275
−5.0 bars	208.0	10.0	2,981
−8.0 bars	195.5	9.3	2,477
$LSD_{(0.05)}$	12.9	0.9	485

* Water stress was imposed in reproductive growth phase (September 10 to September 29, 1991) and measurements were taken on 30 September 1991 (one week after the 50% silking).

**Water stress was imposed in vegetative growth phase (April 25 to May 7, 1992) and measurements were taken on 22 May 1992 (the 50% silking).

Table 2. Influence of soil water deficits on plant dry weights (80 °C for 72 h) of maize Tainung No. 1 in fall crop of 1991 and spring crop of 1992.

Moisture stress treatment	Leaf	Stem	Root	Sum
	g plant^{-1}			
Fall 1991*				
Control	29.48	51.11	18.98	99.57
− 2.5 bars	26.68	47.27	19.73	93.68
− 5.0 bars	24.84	46.82	18.35	90.00
−10.0 bars	22.12	42.79	18.08	83.00
$LSD_{(0.05)}$	3.55	5.01	1.47	7.79
Spring 1992**				
Control	19.46	35.78	17.34	72.58
−2.5 bars	20.28	35.75	17.26	71.77
−5.0 bars	19.55	34.97	15.64	70.15
−8.0 bars	17.31	31.76	14.81	63.87
$LSD_{(0.05)}$	3.93	5.25	3.26	9.97

* Water stress was imposed in reproductive growth phase (September 10 to September 29, 1991) and measurements were taken on 30 September 1991 (one week after the 50% silking).

**Water stress was imposed in vegetative growth phase (April 25 to May 7, 1992) and measurements were taken on 22 May 1992 (the 50% silking).

Table 3. Influence of soil water deficits on the heading and the silking dates of maize Tainung No. 1 in fall crop of 1991 and spring crop of 1992.

Moisture stress treatment	Heading date	50% Heading date	silking date	50% silking date
Fall 1991*				
Control	Sept. 17	Sept. 20	Sept. 19	Sept. 23
− 2.5 bars	Sept. 17	Sept. 21	Sept. 19	Sept. 23
− 5.0 bars	Sept. 17	Sept. 21	Sept. 19	Sept. 23
−10.0 bars	Sept. 17	Sept. 21	Sept. 20	Sept. 25
Spring 1992**				
Control	May 16	May 20	May 18	May 22
−2.5 bars	May 16	May 20	May 18	May 22
−5.0 bars	May 15	May 19	May 18	May 22
−8.0 bars	May 15	May 19	May 18	May 23

* Water stress was imposed in reproductive growth phase (September 10 to September 29, 1991).

**Water stress was imposed in vegetative growth phase (April 25 to May 7, 1992).

Influence of soil water deficits on some yield components of maize measured at harvest were listed in Table 4. It was shown that ear and kernel weights per plant were decreased with decreasing soil water potentials in both crop seasons. Kernel yield was ultimately reduced to 60% of the control at −10 bars in the fall season and to 80% of the control at −8 bars in the spring season (Table 5). Denmead and Shaw (1960) and Lorens *et al.* (1987) showed that soil water deficit during vegetative development of maize decreases vegetative growth, impairs the development of reproductive structures, and may lower kernel yield ultimately. As decreases in net photosynthetic rate associated with decreases in water potential (Boyer, 1970b; Beadle *et al.* 1973; Moss *et al.*, 1961), less photosynthate may be partitioned to vegetative tissues and lower soluble carbohydrate reserves may be retranslocated for reproductive development. Thus, the kernel capacity is smaller and consequently, yield is reduced (Simmons and Jones, 1985; Westgate and Boyer, 1985).

Table 4. Influence of soil water deficits on some yield components of maize Tainung No. 1 measured at harvest in fall crop of 1991 and spring crop of 1992.

Season stress treatment	Ear length	Ear number	Ear dry weight	Kernel dry weight	EPP***
	cm	No. plant^{-1}	g plant^{-1}	g plant^{-1}	%
Fall 1991*					
Control	18.1	1.5	165.97	137.12	86.8
− 2.5 bars	18.1	1.5	142.97	118.24	86.8
− 5.0 bars	17.6	1.4	127.82	105.56	83.1
−10.0 bars	17.4	1.3	106.97	87.45	82.4
$LSD_{(0.05)}$	0.8	0.3	11.09	8.26	5.8
Spring 1992**					
Control	18.2	1.2	166.92	140.38	83.1
−2.5 bars	17.8	1.3	153.66	129.17	79.4
−5.0 bars	18.1	1.3	152.54	127.46	77.7
−8.0 bars	17.5	1.3	141.20	115.81	78.4
$LSD_{(0.05)}$	1.1	0.4	11.57	6.55	6.3

* Water stress was imposed in reproductive growth phase (September 10 to September 29, 1991) and measurements were taken on 21 October 1991.

** Water stress was imposed in vegetative growth phase (April 25 to May 7, 1992) and measurements were taken on 23 June 1992.

***EPP: effective plant percentage.

Table 5. Influence of soil water deficits on yield of maize Tainung No. 1 in fall crop of 1991 and spring crop of 1992.

Moisture stress treatment	Ear dry weight	Kernel yield	Index
	kg ha^{-1}	kg ha^{-1}	%
Fall 1991			
Control	8,240	6,800	100
− 2.5 bars	7,100	5,870	86
− 5.0 bars	6,070	5,010	73
−10.0 bars	5,030	4,110	60
$LSD_{(0.05)}$	800	610	
Spring 1992			
Control	7,740	6,510	100
−2.5 bars	6,970	5,860	90
−5.0 bars	6,760	5,650	87
−8.0 bars	6,200	5,190	80
$LSD_{(0.05)}$	440	490	

* Water stress was imposed in reproductive growth phase (September 10 to September 29, 1991) and measurements were taken on 21 October 1991.

**Water stress was imposed in vegetative growth phase (April 25 to May 7, 1992) and measurements were taken on 23 June 1992.

Kernel yield has also been reported to be sensitive to water deficit during the reproductive growth (Denmead and Shaw, 1960; Grant *et al.*, 1989; Harder *et al.*, 1982; Ouattar *et al.*, 1987b; Westgate and Grant, 1989). In a controlled environment study, McPherson and Boyer (1977) stated that kernel yield of maize exposed to −18 to−20 bars of leaf water potential during kernel-filling period was 47 to 69% of the control yield. Kernel fill of maize can be reduced by drought stress due to decreases in carbon exchange rates (photosynthesis) and /or the duration of kernel fill (Chotena *et al.*, 1980; Classen and Shaw, 1970; Jones and Simmons, 1983; Jurgens *et al.*, 1978; McPherson and Boyer, 1977). Herrero and Johnson (1981) found that moisture stress during anthesis has a greater effect on floral development. Westgate and Boyer (1985) indicated that water deficit occurred at early reproductive phase limited the supply of photosynthate directly from concurrent photosynthesis for the subsequent kernel filling. Ouattar *et al.* (1987a) pointed out that source limitation (decrease of photosynthesis) was the cause of lower kernel weight. In addition, nutrition, nutrient diffusion rate from the soil matrix to roots (Barber, 1962; Olsen *et al.* 1965; Viets, 1972) and nutrient uptake by plants (O' Toole and Baldia, 1982; Verasan and Phillips, 1978; Yambao and O'Toole, 1984) are decreased under soil moisture stress conditions. Such viewpoints support the results of this study.

The linear regressions of kernel yield and growth parameters in maize upon water stress in fall and spring crops were listed in Table 6. It suggested that leaf area, leaf weight and plant weight were three effective parameters in estimating maize production upon soil water deficits occurring in reproductive growth phase. Soil water potential, however, was the only element be employed on predicting maize production by water stress in both growth phases (Fig. 4) and kernel yield reductions depended on severity of soil moisture deficiency.

Table 6. The linear regressions of kernel yieid (Y) and growth parameters (X) in maize upon water deficits in fall crop of 1991 and spring crop of 1992.

Growth parameter	Season	Equation
Plant weight (cm)	Fall	Y=165.2827X−9,686.1950 r=.9944** (p=0.01)
	Spring	Y=121.1160X−2,626.2660 r=.8715 (p=0.13)
Leaf area (cm² plant-1)	Fall	Y=3.1923X−8,151.8110 r=.9974** (p=0.003)
	Spring	Y=1.2342X+2,060.9690 r=.9188 (p=0.08)
Leaf weight (g plant-1)	Fall	Y=371.4876X−4,129.4520 r=.9979** (p=0.002)
	Spring	Y=274.5262X+545.3225 r=.6410 (p=0.36)

r : correlation coefficient.

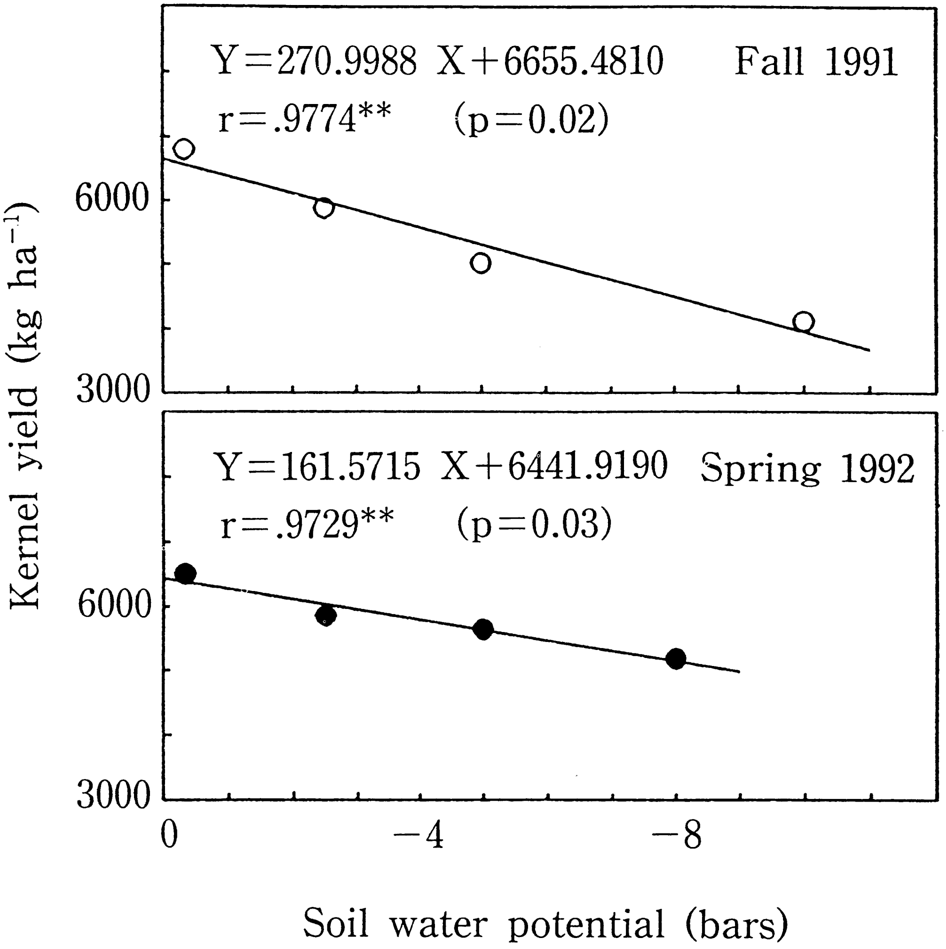

Fig. 4. The linear regression of kernal yield and soil water potential in maize in fall crop of 1991 and spring crop of 1992.

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玉米 (Zea mays L.) 生長與產量對土壤缺水之反應

(二)缺水時期及缺水程度之影響

楊純明 范明仁 向為民

摘 要

水分爲本省玉米生產之一項主要限制因子，因此殊有必要詳加探討各局地環境下玉米生長與產量和土壤水分之關係。本文研究係以玉米單交品種臺農一號爲材料，在臺灣省農業試驗所農場進行田間試驗，評估玉米缺水時期及土壤缺水程度對玉米生產之影響。土壤缺水採人工斷水達成，即在自然狀況下實施停止灌水方式達到預先設定之土壤水分含量，土壤水分潛勢範圍介於－1/3（對照組）至－10 bars 之間。1991年秋作完成生殖生長期缺水處理，而在1992年則完成營養生長期缺水處理。根據試驗結果，玉米每株葉片數不因土壤缺水改變，而當土壤水分潛勢下降至－5 bars（秋作）及－8 bars（春作）時，葉面積明顯減少。營養生長時期13天斷水至－8 bars 時，影響玉米植株高度（於50％雌穗吐絲期測量），惟並未顯著延長或縮短雄穗開花及雌穗吐絲日期。生殖生長時期斷水達－5 bars 時，將造成植株乾重減少10％以上。每公頃穗重及籽粒產量在兩期作均因土壤缺水而降低，秋作在－10 bars、春作在－8 bars 下，籽粒產量分別僅及對照區者之60及80％。本文結果亦發現，在試驗之缺水範圍內，土壤水分潛勢與玉米籽粒產量間呈現顯著直線相關，產量隨土壤水分潛勢下降而降低。

關鍵詞：生長、產量、玉米、土壤缺水、缺水時期、缺水程度。

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1. 臺灣省農業試驗所 研究報告 1668 號。本研究承蒙行政院農業委員會之經費補助（計畫編號81農建—2.1—林—28—2 (5)，特此誌謝。

2. 臺灣省農業試驗所副研究員、研究員及助理研究員。臺灣省 臺中縣 霧峰鄉。

Jour. Agric. Res. China (中華農業研究) 42(2) : 187~199 (1993)

Microorganisms contaminated in the process of cultivation and their effect on the production of shiitake[1]

Ying-Ming Liao[2]

Abstract : Contamination has been a major problem for the shiitake production in Taiwan. To eliminate the contamination to a level as low as possible is very important. In this study, the contaminated microorganisms were identified and the sources of contaminants in the sawdust, spawn, inoculation and incubation rooms, and cultivation yard were described. Attempts were also made to explore the effects of the contaminants on the mycelial growth and/or the yield of shiitake. The effect of medium pH values on the mycelial growth of shiitake and contaminants were also reported. Results indicated that species of *Trichoderma, Penicillium, Neurospora* and *Aspergillus* were the most frequently isolated fungi from the sawdust spawn, while *Trichoderma, Bacillus* and *Aspergillus* were often isolated in the wheat grain spawn. The mycelium of shiitake grew more quickly in the wheat grain medium than it did in the sawdust medium. More microorganisms were trapped in the cultivation yard than in the incubation room. Unused sawdust piled outdoor for 6 months contained more microorganisms than the cultivating one. During marketing or transporting process, population of microorganisms on the surfaces of shiitake fruiting bodies increased greatly. Less amount of microorganisms were found in the normally grown sawdust than in the contaminated sawdusts. The pH value of contaminated sawdust was higher than the normal one, but not much difference was observed in the water contents of the two kind of sawdusts. The pH value of *Castanopsis hytrix* saw-dust was very low within 2 months of piling, but it gradually increased with time and reached ca. 6.0 within 3-4 months which will be suitable for medium perparation. The pH values of *Acacia confusa* and broad leaf trees also increased during piling. The mycelia of shiitake grew best in the acidic conditions when the pH value was between 4.5 and 6.0, while *Trichoderma* grew very well in almost all tested pH values except 7.5 The growth of *Neurospora* was relatively slow in all pH values with pH 6.5 as the most suitable one. When the air temperature was equal to or greater than that of sawdust, less microorganisms were found in the sawdust, however, when the air temperature was lower, more microorganisms were found. In spite of pH values, more shiitake mushrooms were produced in the sawdust medium pasteurized 8 hrs at 98°C than that autoclaved 90 min. at 121°C (15 lb/in^2). The quality of shiitake mushrooms harvested from the former was also better than those form the latter. In the pasteurized medium. yields of the medium with pH values at 5 and 6 were higher than those of the medium with pH 7. Autoclaving completely killed the microorganisms in the sawdust medium while pasteurization only killed those harmful ones.

Key words : Shiitake, Cultivation, Microorganism, Production.

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1. Contribution No. 1669 from the Taiwan Agricultural Research Institute.
2. Assistant Plant Pathologist, Department of Plant Pathology, TARI, Wufeng, Taichung Hsien, Taiwan 413, ROC.

INTRODUCTION

Due to the elite climate, ample source of cultivation material and appropriate technology, Taiwan is an ideal place for the production of edible mushrooms such as common mushroom (*Agaricus bisporus*) and shiitake (*Lentinus edodes*) (12). Either common mushroom or shiitake, parts of its production process such as spawn preparation, inoculation, and incubation etc. are similar. Contamination may occur at any stage of production process from spawning to havesting. Shiitake used to be grown on the logs. However, due to the shortage and increasing price of logs in the last decade, sawdust was currently used mainly for shiitake cultivation(7). In order to reduce production cost, spawn medium was changed from wheat grain to the mixture of sawdust and rice bran. Liao(13,14) reported that *Coriolus versicolor* and *Stemonitis splendens* were the most common decaying fungi on shiitake logs. Moulds were found to be presented in the grain spawn of common mushroom, while *Alternatia, Epicoccum* and *Neurospora* spp. in sorghum spawn and *Mucor* and *Penicillum* spp. in rye spawn(2). Harmful microorganisms, such as *Bacillus, Enterobacter, Listeria, Penicillum, Rhizopus* and *Trichiderma* in cultivation house or sawdust inhibited the mycelial growth of *Pleurotus ostreatus*(4,10,11,17). Fruiting bodies of shiitake may also be browned by *Pseudomonas*(9). Fungicides and/or food preservatives were used to control the contamination caused by *Aspergillus, Neurospora, Penicillium* and *Trichoderma* in the sawdust media of shiitake and *P. ostreatus*(5,8,12,15,16,18). Contamination has been a major problem of the spawn makers and shiitake growers in Taiwan. Therefore, eliminating or reducing the cintamination problem may reduce the production cost and increase the farmers' income. The purposes of this study are : (1) to identify the contaminated microorganisms, sources of contaminants in the sawdust, shiitake spawn, inoculation and incubation rooms, and cultivation yard, (2) to explore the effects of contaminants on the mycelial growth and/or yiekd of shiitake, and (3) to evaluate the effect of medium pH values on the mycelial growth of shiitake and of the contamlnants.

MATERIALS AND METHODS

Strain of shiitake and identification references : The shiitake strain used in this study was obtained from a commercial isolate which is maintained at TARI with a code No. 271. Bacteria and actionomyces were identified basing on Bergey's manual(3), while fungi were identified according to the system describede by Barnett(1).

Inspection and isolation of the contaminating microorganisms in spawn : During the spawn perparation period, visual inspection were conducted daily for one month in the spawn growth room for the percentage of contamination. The contaminated spawns were recorded and identified, if possible to the genus of the fungi or bacteria, and isolated as pure culture on potato dextrose agar (PDA), ntrient agar (beef extract 3g, peptone 5g, agar 15 g, dist. water 1 litre) and Waksman's agar (dextrose 1.0g, KH_2PO_4 0.5g, $MgSO_4 \cdot 7H_2O$ 0.2 g, $Fe_2(SO_4)$ 0.01g, egg albumen 0.25g, agar 15g, dist. water 1 litre) for further studies of identification. The total of 5,000 bottles of wheat grain and sawdust spawns were inspected from May to July and from August to Nov. 1990, respectively.

Trapping of contaminated microorganisms in the air of incubation room and cultirvation yard : Petri dishes (dis. 9 cm) containing potato dextrose agar (pH5.6) , nutrient agar (pH 7.0) or Waksman's agar (pH 8.0) were exposed to the air at the position of 1 m above the ground in the incubation room or cultivation yard for 1 hr. PDA plates were then incubated at 25°C for 96 hrs, nutrient agar (NA) at 36°C for 48 hrs and Waksman's agar at 30°C for 72 hrs for the development of colonies. Five points, 4 corners and the center of the incubation room or cultivation yard, were sampled using two plates for each point. Experiments were conducted in the incubation room at weekly intervals for five times and in the cultivation yard once every month for 7 times.

Isolation of contaminated microorganisms in the sawdust piles, cultivating sawdust bags and fruiting bodies of shiitake from cultivation yard and market : One gram each of the sawdust piled outoors and the sawdust in the cultivation plastic bags were randomly sampled at different times for isolation. After being mixed with 10 ml of distilled water, the samples were homogenized in a Waring blender as a stock solution. Isolation and identification of the microorganisms were conducted in the agar media as described previously with a series of dilution plate method[(5)]. Ten grams of shiitake fruiting bodies harvested from sawdust bags or purchased from the market were sampled and isolated by the same procedure. After incubating as previously described, the microorganisms on the dilution plates were identified and recorded.

Evaluation of the harmful microorganisms to the mycelial growth of shiitake : The isolated harmful microorganisms such as *Bacillus, Pseudomonas, Neurospora, Penicillium and Trichiderma*[(8,9,12,15,18)] were selected for testing their effect on the mycelial growth of shiitake. Ten ml each of the inoculum (1×10^8 cells/mi for bacteria, 7,500 spores/ml for fungi) were added into a sawdust bag which had which had been incoulated for each treatment. The bags were placed at three different cultivation yards in Puli, Wufeng and Mingchien for observation. One month after inoculation, the water content and pH value of the sawdust and the appearance of the bags were recorded. Normal cultivation sawdust bags without inoculation of the testing microorganisms were served as controls.

Change of pH valuses in the piled sawdusts : Sawdusts of the tree species of *Acacia confusa, Castanopsis hytrix,* and a mixture of broad-leaf trees from timber yard were piled (10x10x2.5m, W x L x H) outdoor with out covering. Sawdust pH valuses were measured once a month for 6 times. Ten grams each kind of the sawdust were sampled from the top, center and bottom of the piles with three replicates for pH measurement.

Effect of sawdust pH values on the mycelial growth of shiitake, *Trichoderma* and *Neurospora* : The pH values of sawdust were adjusted to 4.5, 5.0, 5.5, 6.0, 6.5, 7,0 and 7.5 with calcium carbonate powder or 300 ppm of citric acid solution. After pasteurization (98°C, 8 hrs) , 30ml of the adjusted sawdust were placed and pressed into a petri plates (diam. 9cm) for inoculation. Pure cultrues of shiitake, *Trichoderma* and *Neurospora* on PDA were used as inocula. One agar disc from each pure culture (diam. 0.5cm) was inoculated on to the center of the sawdust medium in petri dish. Sizes of the colonies were measured after incubation for 14 days at 24°C.

Evaluation of disinfection method and sawdust pH value on the degree of contamination and yield of shiitake : Sawdust medium containing water (60%) , sawdust (33.3%) , rice bran (4%) and wheat meal (2.7%) was adjusted with calcium carbontae or citric acid as previously described to obtain pH values at 5.0, 6.0 and 7.0 for testing. Polypropylene plastic bags containing 1.5Kg of the prepared medium were sterilized at 121°C, 151b/in^2, for 90min or pasteurized at 98°C for 8hrs. After cooling and before the inoculation of shiitake spawn, microorganisms in the bags were detected by the dilution method as previously described. The bags were then inoculated with shiitake spawn for the production of shiitaks fruiting bodies. The period from inoculation to the formation of fruiting bodies as well as the fresh weight of fruiting bodies per bag were recorded.

RESULT

Contaminated microorganisms in the shiitake spawns : As shown in Table 1, *Trichoderma, Penicillium, Neurospora,* and *Aspergillus* were the most frequently found microorganisms in the sawdust spawns, while *Trichoderma, Bacillus, Penicillium* and *Aspergillus* were often isolated in the wheat grain spawns. Percentage of contamination was recorded as 2.76 % or 134 bottles out of 5,000 bottles in the wheat grain spawns and 2,16% or 108 bottles in the sawdust spawns. The mycelium of shiitake grew more quickly in the wheat grain medium than that in the sawdust medium.

Table 1. Number and percentage of contaminated microorganisms in the shiitake wheat grain and sawdust

Mircroorganism	Wheat grain spawn*		Sawdust spawn	
	infected bottles	%	infected bottles	%
Alternaria sp.	2**	1.5***	1**	0.9***
Aspergillus sp.	15	11.2	10	9.3
Bacillus sp.	18	13.4	4	3.7
Bacteria unidentified	4	3.0	2	1.9
Chaetomium sp.	5	3.7	8	7.4
Fusarium sp.	5	3.7	6	5.5
Fungi unidentified	4	3.0	1	0.9
Helminthosporium sp.	11	8.2	8	7.4
Penicillium sp.	15	11.2	16	14.8
Pseudomonas sp.	11	8.2	2	1.9
Trichoderma sp.	38	28.4	34	31.5
Mucor sp.	2	1.5	4	3.7
Neurospora sp.	4	3.2	12	11.1
Total	134	100	108	100

*. Spawns were kept in the incubation room at 20°C. Days required from ionculation of shiitake inoculum to cover the whole bottles of medium were 30 days for wheat grain spawns and 35 days for sawdust spawns. Experiments for wheat grain spawns and sawdust spawns were conducted from May to July, and from August to November, 1990, respectively.

**. Accumulated number of the contaminated bottles in one month of observation from 5,000 bottles of spawns.

***. Percentage of the contaminated microorganism per se over the total number of contamination.

Contaminated microorganisms in the air of incubation room and cultivation yard : Because the incubation room is always disinfected with chemicals before use. Therefore, there was only a few number of microorganisms trapped in the air. However, the population of microorganisms increased with incubation time. Trapping efficacy varied with different media for testing. PDA was more suitable for trapping fungi, and NA for bacteria. Only a few amount of microorganisms were trapped in waksman's agar. In the cultivation yard the number of trapped microorganisms was greatly affected by the air temperature. Least number was observed in January or February which was the coldest season in Taiwan. More microorganisms were trapped in the air of cultivation yard than that in the incubation room (Table 2, 3).

Table 2. Colony number of the microorganism trapped in the air of incubation room at different times.*

Week after inoculation of shiitake	Bacteria/plate			Fungi/plate		
	PDA**	NA	WA	PDA	NA	WA
1	2***	6	2	4	0	1
2	2	14	4	18	1	1
3	4	18	5	35	3	1
4	5	20	8	40	3	2
5	6	26	8	44	4	3
Average	3.8	16.8	5.4	28.2	2.2	1.6

*. Sampling was conducted at 1 m above the ground in the incubation room (22°C) of shiitake.
**. PDA : potato dextrose agar ; NA : nutrient agar ; WA : Waksman's agar.
***. Colony number of the medium in a petri plate (diam. 9cm) exposed to the air for one hr and then incubated 96 hrs at 25°C for PDA ; 48hrs at 36°C for NA and 72 hrs at 30°C for WA. Each numger was the average of 10 plates. Colony of actinomyces was included in bacteria.

Table 3. Colony number of the microorganism trapped in the air of cultivation yard*

Month after inoculation of shiitake	Cultivation stage of stiitake	Bacteria/plate			Fungi/plate		
		PDA**	NA	WA	PDA	NA	WA
0	Inoculation	8***	28	16	30	6	8
1	Incubation	12	36	16	80	16	4
2	Incubation	11	24	10	87	12	4
3	Incubation	6	20	7	45	6	3
4	Incubation	4	22	7	32	4	3
5	Fruiting	2	9	4	21	8	2
6	Harvesting	16	43	22	115	24	10
Average		8.4	26.0	11.7	58.6	10.9	4.9

*. Sampling was conducted at 1 m above the ground in the incubation room (22°C) of shiitake.
**. PDA : potato dextrose agar ; NA : nutrient agar ; WA : Waksman's agar.
***. Colony number of the medium in a petri plate (diam. 9cm) exposed to the air for one hr and then incubated 96 hrs at 25°C for PDA ; 48hrs at 36°C for NA and 72 hrs at 30°C for WA. Each number was the average of 10 plates. Colony of actinomyces was included in bacteria.

Microorganisms in different kind of sawdusts and fruiting bodies : In general, sawdust piled outdoor for 6 months contained more microorganisms than the cultivating one and most of these microorganisms were bacteria and actinomyces. Fresh fruiting bodies right after being harvested contained the least amount of microorganisms on their surfaces. During the matketing or transportation process, population of the microorganisms on the surface of fruiting bodies increased greatly (Table 4).

Table 4. Comparison of cfu of microorganisms presented in the sawdust piled outdoor, cultivating sawdust with shiitake mycelia, and fruiting bodies from cultivation yard and/or purchased from market.

Medium	sawdust piled 6 months outdoor	Cultivating sawdust with shiitake mycelia	Fruiting bodies from cultivation yard	Frutitng bodies from marker
Potato dextrose agar	8×10^{6}*	7×10^{4}*	8×10^{5}**	6×10^{4}*
Nutrient agar	4×10^{8}	6×10^{6}	5×10^{5}	6×10^{8}
Waksman's agar	6×10^{7}	4×10^{6}	4×10^{4}	3×10^{7}
Average	1.6×10^{8}	3.4×10^{6}	3.1×10^{5}	2.1×10^{7}

*. Colony forming unit (cfu) of microorganism presented in one gram of sawdust, data were estimated with a dilution plate method, microorganism included fungi, bacteria.

**. Number of microorganism presented in 10 grams of fresh fruiting bodies harvested in the cultivation yard or purchased from market. Shiitake mycelium colonies were not included.

Comparison of the microorganisms in the normal and contaminated cultivating bags at different locations : Results indicated that less amount of microorganisms were presented in the normally grown sawdust than in the contaminated ones. The pH value of contaminated sawdust was higher than that of the normal one. No difference was observed between the water contents of these two kind of sawdusts. Among the three cultivation yards, the number of microorganism detected in sawdusts in decending order was Wufeng, Mingchien, and Puli where were 80m, 250m and 400m above the sea level respectively. This indicated that cooler place is more suitable for the growth of shiitake (Table 5). Mycelial growth of shiitake was completely inhibited in the sawdust medium inoculated or contaminated with harmful microorganisms such as *Trichoderma, Neurospora, Aspergillus, Penicillium, Bacillus* and *Pseudomonas* (Fig. 1).

Table 5. Comparison of microorganim, water content and pH values in the contaminated cultivating bags at different locations*

Location	Normal cultivating bags			Contaminated cultivating bags		
	number of microorganism per gram of sawdust (cfu/plate)	water content of sawdust (%)	pH value of sawdust	number of microorganism per gram of sawdust (cfu/plate)	water content of sawdust (%)	pH value of sawdust
Puli (400 m above sea level)	3×10^{4}	64	4.0	1×10^{9}	61	6.0
Wufeng (80 m above sea level)	4×10^{5}	63	3.8	6×10^{9}	60	6.2
Minchien (250 m above sea level)	8×10^{4}	64	4.1	3×10^{8}	61	6.2

* Data were based on the average of 20 bags one month after the inoculation of shiitake spawns.

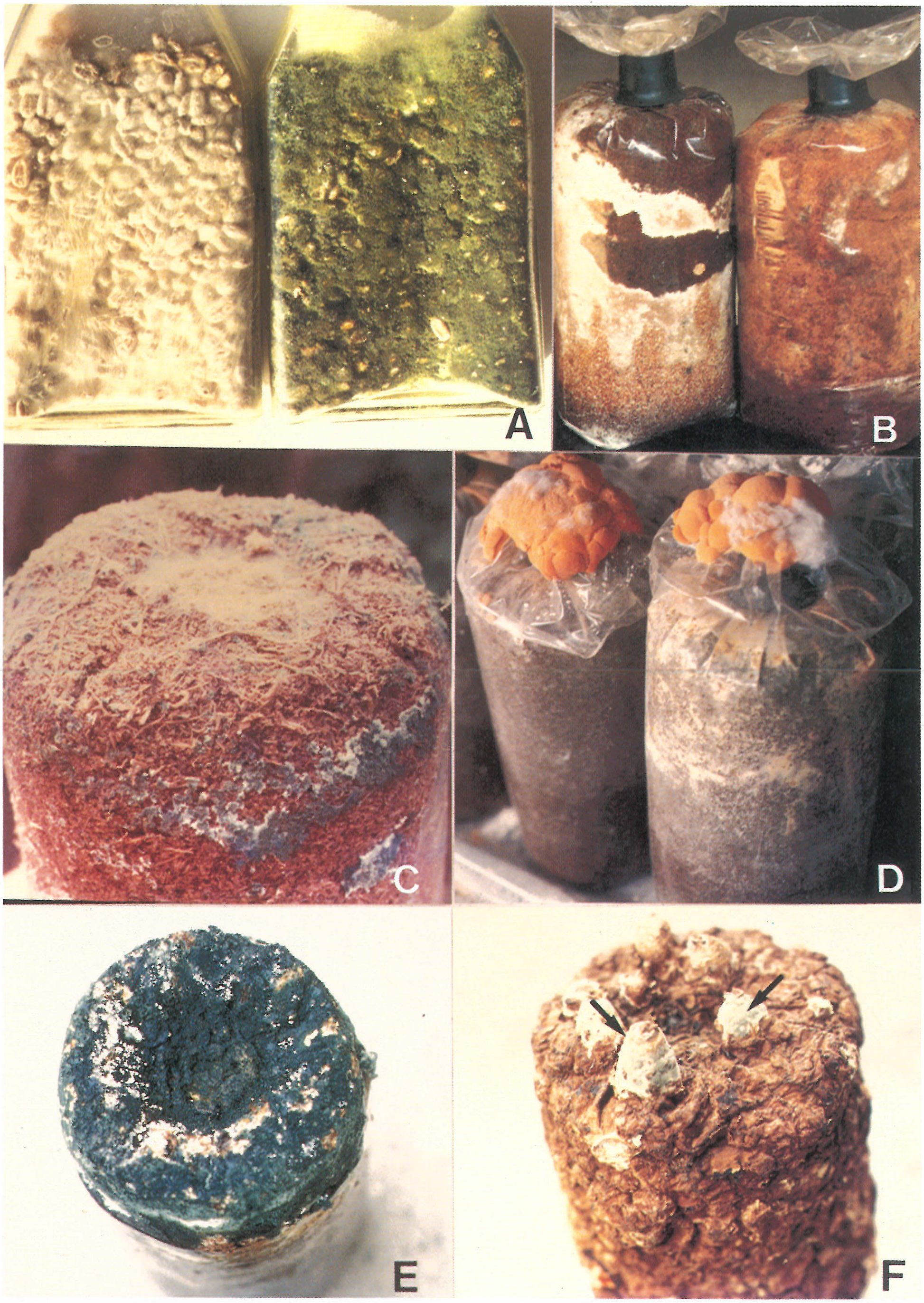

Fig. 1. Microorganisms affecting the growth of mycelium and fruiting body of shiitake : A. *Trichoderma* on wheat grain spawn (right) and healthy control (left) ; B. *Bacillus* stopped the mycelial growth (left) and *Pseudomonas* caused rotting of sawdust medium (right) ; C. *Penicillum* stopped the mycelial growth of shiitake ; D. *Neurospora* stopped the myeclial growth of shiitake ; E. *Trichoderma* stopped the mycelial growth of shiitake ; F. *Trichoderma* stopped the growth of fruiting bodies (arrow points) of shiitake.

Change of pH values in the piled sawdust : The pH value of the sawdust of *C. hystrix* was very low within the first two months of piling. It gradually increased with time and reached ca. 6.0 in 3-4 moths which is a suitable level for the preparation of sawdust medium. The pH values of *A. confusa* sawdusts and broad leaf trees also increased with time of piling. However, the change of their pH was not as evident as that of *C. hystrix* (Table 6).

Table 6. Comparison of pH value in various kind of sawdusts piled for different times*

piling time (month)	Sawdust pH value of		
	C. hystrix	A. confusa	mixed broad leaf trees
0	3.42	5.93	5.20
1	4.55	6.09	5.88
2	5.02	6.95	6.21
3	5.67	6.63	6.44
4	6.61	6.05	6.40
5	5.98	5.93	5.65
6	5.95	5.90	5.63

*. Date were based on the average of three replicaties.

Effect of sawdust pH values on the mycelial growth of shiitake, *Trichoderma* and *Neurospora* : The mycelium of shiitake grew best in the acidic conditions where the pH value was between 4.5 and 6.0. *Trichoderma* grew well in almost all tested pH values except 7.5. The growth of *Neurospora* was relatively slow in all pH values with pH 6.5 as the most suitable one (Table 7, Fig. 2).

Table 7. Effect of sawdust pH value on the mycelial growth of shiitake, Trichoderma and Neursopora

pH value	Colony size* (cm) of		
	Shiitake	Trichoderma	Neurospora
4.5	9.0	9.0	1.0
5.0	9.0	9.0	1.0
5.5	9.0	(9.0)**	1.4
6.0	8.2	(9.0)**	2.3
6.5	3.2	9.0	2.7
7.0	0.8	9.0	1.0
7.5	0.5	0.6	1.0

*. Data were the average of 3 replicates. Fungi were grown on sawdust medium 14 days at 24°C.
**. The mycelial growth of Trichoderma were relatively loose and rare.

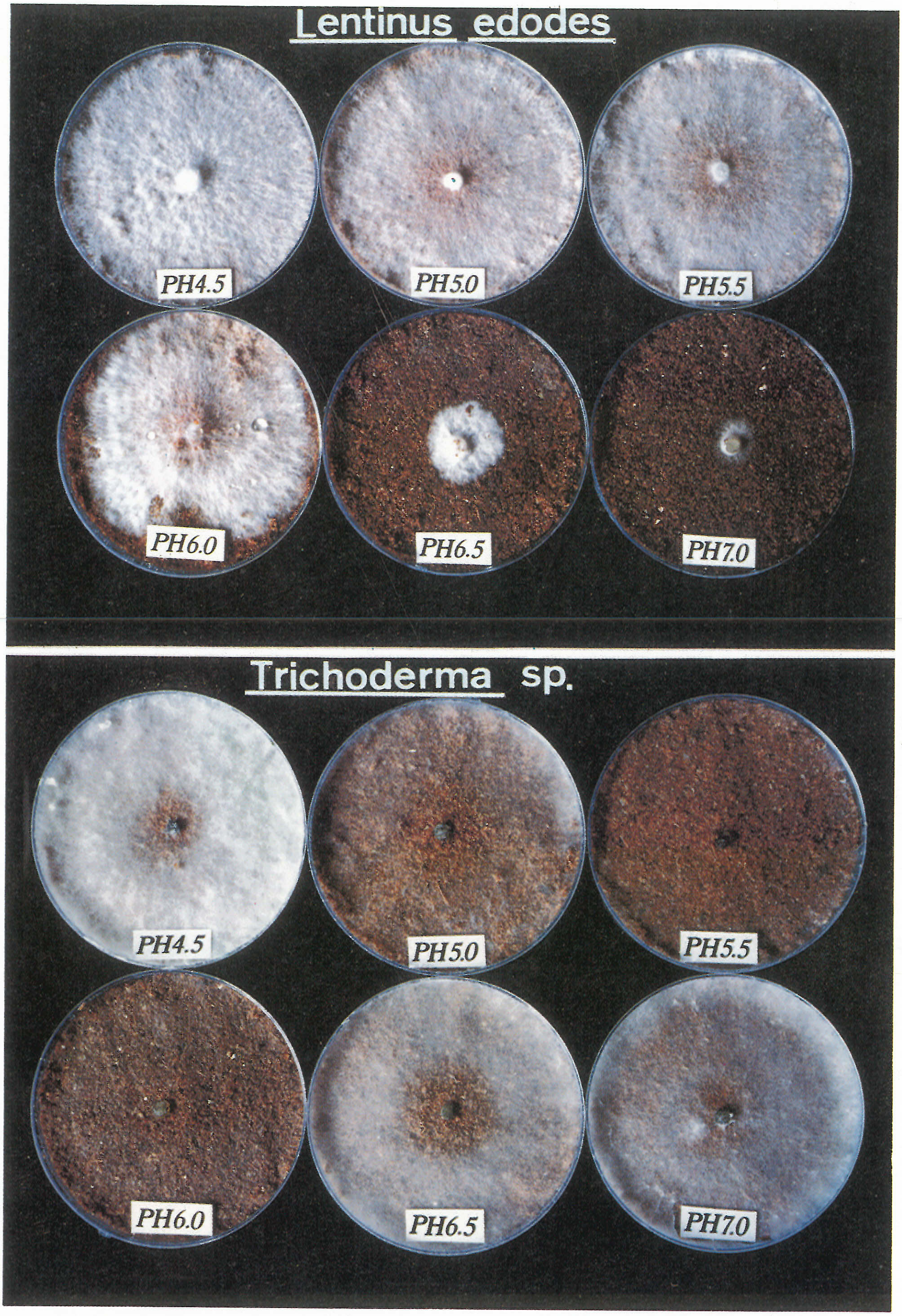

Fig. 2. Effect of pH values of sawdust medium on the mycelial growth of *Lentinus edodes* (top) and *Trichoderma* sp. (bottom).

Relationship between the air or sawdust temperature and the number of microorganisms in the sawdust at different stages of shiitake cultivation : Air and sawdust temperatures varied with the seasonal changes of temperature. When the air temperature was high in the natural condition, the tmeperature of the air and sawdust in the cultivation yard also were high. The number of microorganisms detected in the sawdust medium was coincided with the temperature difference between the sawdust and air. When the air temperature was lower than that of sawdust, more microorganisms were existed in the sawdust. Microorganism population was found to be not correlated to the cultivation stages of shiitake (Table 8).

Table 8. Relationship between number of microorganisms in the sawdust and temperatures of air and medium at different stages of shiitake cultivations*

Date	Stage of cultivation	Temperature (°C) of		Number (cfu) of microorganism ** (Per gram of sawdust)
		Air	Sawdust	
15. Sept. 1989	inoculation	24	24	4×10^3
10. Oct. 1989	middle mycelial growth	25	28	3×10^6
25. Oct. 1989	complete mycelial growth	22	21	2×10^4
15. Feb. 1989	fruiting body formation	18	19	3×10^5

*. Data were the average of 10 bags at Wufeng. Taichung (80 m above sea level).
**. cfu : colony forming unit.

Effect of disinfection method and different sawdust pH values on the contamination and yield of shiitake : In spite of pH values, more shiitake was produced in the sawdust medium disinfected or pasteurized 8 hrs at 98°C than that autoclaved 90 min at 121°C (15 1b/in^2). The quality of shiitake harvested from the pasteurized medium. However. better than that harvested from the sterilized or autoclaved medium. However, pasteurized medium took 10-45 days more to produce fruiting bodies. In the pasteurized medium, the yields of medium with pH values at 5 and 6 were better than the medium with a pH value at 7. However, no differences were observed among the yields of autoclaved sawdust medium with different pH values. Autoclaving completely killed the microorganisms in the sawdust medium while pasteurization only eliminated the harmful ones (Table 9).

Table 9. Effect of disinfection method and pH value of sawdust on the yield and quality of stiitake as well as the number of microorganism

Disinfection method	Survey items	pH value of the sawdust		
		5.0	6.0	7.0
121°C, 15 1b/in^2 for 90 min	Fresh shiitake (g/bag) *	210a	215a	200a
	Inoculation to fruiting (days)	100	105	135
	Quality of fruiting body	large number of small fruiting bodies	large number of small fruiting bodies	large number of small fruiting bodies
	microorganism/g sawdust ** (cfu)	0	0	0

(continued)

98°C for 8 hrs	Fresh shiitake (g/bag) *	240b	255a	220c
	Days from inoculation to fruiting	110	115	150
	Quality of fruiting body	large number of normal fruiting bodies	large number of normal fruiting bodies	large number of normal fruiting bodies
	microorganism/g sawdust ** (cfu)	3×10^2	4×10^2	8×10^4

*. Data within row followed by the same letters are not significantly different (p=0.01) according to D M R test. Data were the average of 200 plastic bags from 5 harvesting.
**. Number of microorganisms were detected before the inoculation of shiitake spawns.

DISCUSSION

Contamination of microorganism is a very important problem in the cultivation of edible mushrooms. This study revealed that contamination problem in the wheat grain spawns is greater than that in the sawdust spawns. This is possibly because the wheat grains provides more nutrients for the growth of microorganism especially bacteria than the sawdust. Since spawn cost is becoming more popular in the last decades.

Although Binter(2) reported that the important pathogens, such as *Mycogone* and *Diehliomyces,* were not presented in the spawn of common mushroom, this research indicated that the important pathogen of shiitake production in sawdust bags such as *Trichoderma,* was presented in the spawns and also in the air of the incubation room and cultivation yard (Table 2,3). Therefore, in order to reduce the percentage of contamination during the preparation process of spawns, establishment of a laminar flow filter system in the inoculation and incubation rooms is necessary. Good pasteurilization of the sawdust is also very important which may reduce the sources of primary inoculum. Good management of the environments in the incubation room and cultivtion yard may reduce the contamination of cultivation bags. The amount of microorganisms on the surfaces of fruiting bodies (Table 4) during marketing or transportation process may be reduced by precooling or low temperature storage. Cultivation trials at three locations showed that higher altitude areas are more suitable for the growth of shiitake than in the low altitude areas (Table 5). This is possibly because the low temperature favored the mycelial growth and fruiting of shiitake and the growth of contaminating microorganisms were reduced.

The change of pH values in the sawdust of different tree species piled for different time of piling (Table 6) showed piling not only changed the pH value but also changed the microflora in the sawdust. Different fungi have their own suitable optimal pH values for their growth (Table 7). Population change of the microorganisms in different stages of cultivation indicated that not only the temperature of the air the sawdust but also the biological activity influenced the population density of the microorganisms. In the early stage, because sawdust was just pasteurized or autoclaved, the population of harmful microorganism was very low in it. However, after inoculation of shiitake spawn, the population increased with time. The biological heat released by shiitake mycelium also favored the growth of harmful or contaminated microorganisms (Table 8). Disinfection experiments indicated that pasteurization at 98°C for 8 hrs was better than sterilization (Table 9)

because sterilization eliminates all the microorganisms in the medium, including those beneficial ones.

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香菇栽培之污染微生物及其對香菇生產之影響[1]

廖 英 明[2]

摘 要

香菇污染雜菌一直是香菇栽培者及菌種製造者之主要問題，而減少污染程度則是降低成本及增加收益的方法。本文旨在檢測存在於菌種、木屑及培養基或栽培場、培養室等之微生物，及這些微生物對香菇生產之影響，進而尋求適當之 pH 值與殺菌方式以便降低微生物之污染藉以改進香菇栽培技術。由試驗結果可知，在香菇木屑菌種中常見之雜菌以 *Trichoderma, Penicillium, Neurospora* 及 *Aspergillus*最多，而在麥粒菌種中則以 *Trichoderma, Bacillus* 及 *Aspergillus* 爲主。香菇菌絲在麥粒菌種中之生長速度比在木屑菌種中爲快。在栽培場所收集之微生物數量比在接種室或培養室者爲多，而堆積在戶外之木屑其微生物含量又比在木屑培養基中者爲多。在運輸販賣過程中香菇子實體表面會污染許多微生物。將這些有害微生物接種於木屑包，則可發現正常生長之木屑包其微生物量較污染包爲低且 pH 值也較低，含水量則正常包比污染包稍高，但差異不大。木屑在戶外堆積六個月後可發現火燒柯（*Castanopsis hytrix*）由原來的低 pH 值漸漸昇高爲適合香菇生長的範圍，而相思樹（*Acacia confusa*）及闊葉樹混合木屑也有相同的結果，惟其變化不如火燒柯大。酸性木屑培養基極適合香菇菌絲之生長，較適合之 pH 值爲4.5至6.0，*Trichoderma* 則除了pH7.5外，所有供試之範圍均適合生長，而 *Neurospora* 則在所有測試 pH 值中均生長緩慢，只有 pH6.5較適合。當氣溫高於或等於木屑包溫時，則微生物量較少，反之木屑包溫高於氣溫時，則微生量較多。不論木屑包在何種 pH 值，若以98°C，8小時殺菌之處理時，香菇的產量或品質均優於用121°C（151b/in^2），90分之殺菌方式。後者之殺菌方式除了可殺滅害菌外，其它有益微生物也一併殺死，而 pH 5 及 pH 6 則在產量及菇質方面均優於 pH 7。

關鍵詞：香菇、栽培、微生物、生產。

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2. 本所植物病理系助理研究員。臺灣省 臺中縣 霧峰鄉。

中華農業研究（Jour. Agric. Res. China）42(2)：200～215（1993）

不織布浮動層覆蓋熱環境模式之研究[1]

陳加忠[2]　陳邦華[3]　曹之祖[2]

摘要：在此研究推衍不織布浮動層覆蓋設施之熱環境模式以預測設施內部之溫度。覆蓋物之傳導與對流熱傳係數利用部份之量測數據配合迴歸分析技術加以評估。模式之預測性十分合理，其準確度在1.5°C之內。影響覆蓋物內部溫度之主要因子爲大氣日照量，大氣溫度與風速。

關鍵詞：不織布、浮層覆蓋、熱環境模式。

爲改良農作物於冬日生長之環境，各種不同之農業設施普遍爲農民所應用，利用不織布覆蓋於作物之上即爲其中一例。美國自1981年將不織布作爲農業生產的被覆材料之後，由於不織布質料輕而通氣，不壓抑作物的生長，可直接覆蓋於作物上，無須立支柱，可節省人工，因此近十年來大量用於蔬菜生產上，尤其對於葫蘆科作物可達到調節產期之目的 ， 其作用爲保溫、防霜、防蟲、防鳥與防風等。

目前國內已有廠商以聚丙烯（Polypropylene）爲原料，製成連續長纖維之紡結不織布，其化學式爲$(C_3H_3)x$，基重有10、14、17、20、23、30、42與50g/㎡，可視栽培作物之種類而使用不同基重之不織布。不織布具有質輕、柔軟無毒、日光透過率高、熱量透過率低、日間保溫強、夜間能吸收紅外線、可防止溫度急降、有親水性、可吸水及透濕，故不致結露、滴水而發生冷害等特性。

農業設施對農作物栽培之影響研究項目已爲國內農業氣象之研究重點，因此已有豐富之參考文獻。如利用 PE 布隧道進行冬日苦瓜之栽培[(1)]，以高架式塑膠布設施進行檬果生產之影響[(2)]，或是探討不同栽培設施對洋香瓜生產之影響[(3)]。以不織布預防蔬菜冬日之寒害研究[(4)]，遮雨棚架對芥菜採種之應用[5)]，與比較不同田畦覆蓋材料對甜椒生育之影響[(6)]等研究也在近年內開始著手執行。然而在大多數之設施應用研究中，有關微氣候之研究僅爲數據之收集與定性之敘述，對於設施內溫、濕度、日照量等微氣候因子與外界自然環境，設施自身條件之量化關係未曾加以建立。因此研究之結果僅能說明特定時間，地區下特定作物之生產狀況，缺乏普遍性之應用價值。國內在有關養殖池之生態研究中[(7)]，雖然曾利用迴歸技術建立溶氧量與氣溫，水溫及風速之迴歸模式，但因模式並非來自物理原理之推衍，而僅是由氣象資料之記錄結果加以計算而得，因此應用之價值上不大。

設施環境模式建立之目的如同溫室環境模式[(8)]：(一)量化外界大氣環境與設施自身條件（結構、材料……等）對內部微氣候之影響，(二)配合作物栽培條件做爲設施栽培之決策規劃。國內完整之溫室環境模式研究已完成建立與評估[(8,9)]，並推衍此型模式探討內外遮蔭對溫室內微氣候之影響[(10)]。

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1. 臺灣省農業試驗所　研究報告第 1670 號。
2. 本所農工系副研究員、技士。
3. 本所農場管理室助理研究員。

國外對溫室內部微氣候模式之評論（Review）已有多篇[8]。在設施方面，以地面直接覆蓋（Mulch）之研究最爲完善，包含地面與地層之複雜傳遞現象均已建立模式並加以驗證[16,19]。在隧道型設施（Row Cover）研究方面[13,18]，包含與不包含地面覆蓋物之隧道型設施已利用熱傳原理建立模式，並對不含地面覆蓋之隧道型設施進行驗證研究[13]。

此研究之目的在於以浮動層不織布覆蓋設施（Floating mulches of non-woven fabrics）爲研究對象，進行其設施內部熱環境模式之推衍，並實際量測此型設施內外之氣象因子以驗證模式之符合性，並依模式探討影響浮動型不織布覆蓋栽培之主要因子。

環境模式之建立

此熱環境模式以日照量與溫度爲探討因子，相對濕度物性屬於質傳環境，在溫度之模式預測準確時即可依質量平衡原理加以推衍。

模式之參數條件如日照量、大氣溫度、地溫、風速等爲現地量測值，以符合本省不穩定氣候之狀況。

典型之不織布覆蓋微氣候熱環境系統如圖1所示，此系統之假設條件如下：

一、系統內溫度均勻分布，無熱力場梯度現象。

二、熱傳導，對流係數不因溫度而改變。

三、熱傳導係數爲定值，不因溫度、波長而改變。

四、僅考慮垂直方向一維熱傳系統，平面方向加以忽略。

五、系統內植物對熱系統之影響可加以忽略。

六、系統熱傳僅土壤熱傳遞與時間相關，傳遞爲垂直方向，空氣之溫度變化爲規定狀況。

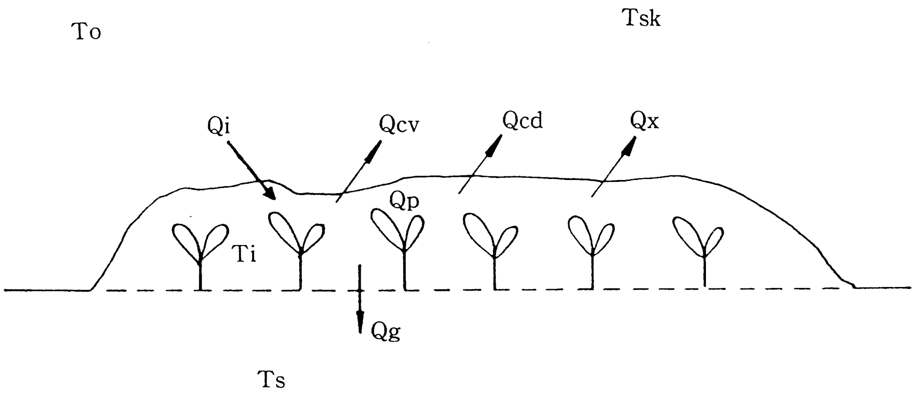

圖1.　不織布浮動型覆蓋熱環境系統

Fig. 1.　Thermal environment system for floating mulches of the non-woven fabrics

熱環境系統之符號說明如下，能量應用單位爲 W/m²，溫度單位爲°C。

Q_i：進入設施內之太陽能量。

Q_{cd}：內部對外界之熱傳導能量。

Q_{ev}：內部對外界之熱對流能量。

Q_t：內部對外界之熱長波輻射能量。

Q_g：內部對地面之傳導能量。

Q_p：植物所利用之能量。

T_o：外界大氣溫度。

T_i：內部空氣溫度。

T_s：地底土壤溫度。

各項能量之計算公式如下：

1. Q_l：

$$Q_l=\pi \cdot I_s \cdot A_f \quad (1)$$

π：太陽能量穿透覆蓋物之部份，π為常數。

I_s：外界太陽能量（w/m²）

A_f：地面面積（m²）

2. Q_{cd}：

$$Q_{cd}=UK \cdot A_\omega \cdot (T_i-T_o) \quad (2)$$

UK：熱傳導係數，在不織布厚度一定之時，UK 之單位為 W/m²，°C。

A_ω：周壁面積（m²）

3. Q_{cv}：

$$Q_{cv}=U_c \cdot A_\omega \cdot (T_i-T_o) \quad (3)$$

U_c：熱對流係數，單位為 W/m²・°C

4. Q_t：

$$Q_t=\pi_t \cdot A_f \cdot \sigma \cdot (T_{ik}^4-T_{sk}^4) \quad (4)$$

π_t：長波熱傳係數（Thermal tranmittance）

σ：波茲蔓常數，$5.67*10^8$ W/m²・$_k{}^4$

T_{ik}：內部氣溫，單位（°K）

T_{sk}：天空溫度，單位（°K），其計算式利用 Albright 等人之研究[13]：

$$T_{sk}=0.0552\ (T_{ik})^{1.5} \quad (5)$$

5. Q_g：

$$Q_g=A_f \cdot GE\ (t) \quad (6)$$

GE（t）：土壤熱傳量（W/m²），為時間與日照量之影響函數。

$$GE=K_g \cdot A_f * (T_i-T_s) \quad (7)$$

T_s：地層溫度，K_g：土壤熱傳導常數（W/m² C）

6. Q_p：

植物因呼吸作用，光合作用所利用之能量，在覆蓋設施生產時均加以忽略[13,16]依熱能平衡原理，設施內部之熱平衡系統量化模式為：

$$Q_i=Q_{cd}+Q_{cv}+Q_t \pm Q_g \quad (8)$$

在模式應用中，熱對流係數，U_c 與外界風速之關係有如下之公式[14,18,19]

$$U_{c1}=a_1，a_1 \text{ 為常數。} \quad (9)$$

$$U_{c2}=b_1+b_2 \cdot V \quad (10)$$

b_1、b_2 為常數，V 為風速（m/sec）

$$U_{c3}=C_1 \cdot V^n \quad (11)$$

$$U_{c4}=C_2+C_3 \cdot V^n \quad (12)$$

C_1，n 為常數，n 介於0.5～0.8之間。

代入公式（9）～（12）至公式（8），熱平衡系統模式之型式可歸納如下：

$$\pi \cdot I_s - d_1 \cdot K \cdot (T_l - T_o) - \pi_t \cdot \sigma \,[T_{lk}^4 - T_{sk}^4] - K_g \cdot (T_l - T_s) = 0 \quad \cdots\cdots (13)$$

$$\pi \cdot I_s - (e_1 + e_2 \cdot V) \cdot K \cdot (T_l - T_o) - \pi_t \cdot \sigma \,[T_{lk}^4 - T_{sk}^4] - K_g \cdot (T_l - T_s) = 0 \quad \cdots\cdots (14)$$

$$\pi \cdot I_s - (f_1 + f_2 V^n) \cdot K \cdot (T_l - T_o) - \pi_t \cdot \sigma \,[T_{lk}^4 - T_{sk}^4] - K_g \cdot (T_l - T_s) = 0 \quad \cdots\cdots (15)$$

$$K = Aw/A_f \quad \cdots\cdots (16)$$

由於公式（13）～（15）中包含 T_l 之四次項，無法以代數公式直接求解，此計算中利用數值分析 Bi-section 法計算未知數。

材料與方法

一、不織布材料

此研究所利用之不織布覆蓋材料共有兩種：17g/m²與30g/m²。原料爲聚丙烯。

二、作物栽植

此實驗自80年12月至81年3月於農業試驗所農場實施，種植作物爲莧菜，地面作畦，每畦寬約1.2 m。利用兩型不織布覆蓋材料平鋪於作物之上進行浮動型覆蓋栽培（Floating Covering Culture）。

三、微氣候量測

研究過程中量測大氣溫度，相對濕度，日照量（W/m²），風速（m/sec），地面溫度。覆蓋設施內空氣溫度，相對濕度，日照量，地面溫度。量測所用設備如下：

1. 氣溫、相對濕度：利用 Rotronic Hygrometer I-100 Transmitter，溫度感測元件爲 RTD PT-100 Ohm，濕度爲電容元件 Rotronic C-83-N 型。其輸出信號0-1V，相對於0-100°C，0-100% RH，並有太陽光遮蓋裝置（Shield），以避免熱輻射引起之量測誤差。
2. 地溫：利用熱電偶線（K-Type），其外面以金屬套筒包覆，構造與放置方式如文獻（22）所描述，量測點於地面下5公分處。
3. 日照量：利用 Eppley Radiometer（Moder 8—48）型日照計與 INS-TARI 型日射計，使用前皆加以校正[10]。輸出訊號爲 mv 值，經放大後輸入記錄器。
4. 風速：風速資料利用距離量測現場50m附近農業氣象觀測站之資料。
5. 數據記錄器：氣溫、相對濕度與日照量均由電壓記錄器（Ling-Shyh型，LS-ELR-48 Model）加以直接記錄，熱偶線溫度係利用 Data Logger Model 3020T 型加以記錄，製造廠商爲 ECD（Electron Controls Design INC.）

四、參數數值選擇：

此研究中熱環境模式（公式（13）～（15））中涉及之參數，有π，d_1，e_1，f_1，π_t 與 K_g 等，其數值之選擇，判定如下：

1. π：太陽能入射率（小數點），以實際量測值計算。

$$\pi = I_l/I_s \quad \cdots\cdots (17)$$

I_l：穿過不織布覆蓋物之日照量。

I_s：地面之日照量。

2. π_t：長波熱輻射係數，由 Kurata 氏[15]對不織布浮動式覆蓋之研究結果，30g/m² 不織布之 π_t 值爲 0.7，17g/m² 不織布之 π_t 值爲0.88。
3. d_1、e_1、f_1 與 K_g 值：

由於不織布之熱傳物性在傳導與對流係數方面無已知資料可加以參考，K_g 值之數據值因其影響因子極多，缺乏可靠之數據，此研究利用線性迴歸方式，評估此參數值[12,14]。其方法介紹如下：

(1)以所量測之微氣候數據任選三～四天之資料爲參數抉擇之用，提供爲統計技術迴歸分析數據。

(2)以上述1，2項所得之 π，π_t 值，配合微氣候之量測值，T_1k，T_{sk} 分別計算Q_t 值。

(3)由實測 A_f、Aw 值可計算 K=1.2。

(4)以公式（14）爲例，公式重新排列如下：

$$\pi I_s - Qt = (e_1 + e_2 V) \cdot K \cdot (T_1 - T_o) - K_g (T_1 - T_s) \quad \cdots\cdots (18)$$

令 $g_1 = K \cdot e_1$，$g_2 = K \cdot e_2$

每一實測點之數據可以迴歸方程式之形式表示：

$$Yi = g_1 \cdot X_{1i} + g_2 \cdot X_{2l} - K_g \cdot X_{3l} \quad \cdots\cdots (19)$$

$Yi = \pi I_{sl} - Q_{tl}$，$X_{1l} = (T_{1l} - T_{oi})$，$X_{2l} = V_l (T_{1l} - T_{2l})$，

$X_{3l} = (T_{1l} - T_{sl})$

$$Q_{tl} = \pi_t \cdot \sigma \cdot (T_{1k}{}^4 - T_{skl}{}^4) \quad \cdots\cdots (20)$$

公式（19）爲典型不包括常數項之線性迴歸方式式[17]。

(5)執行迴歸分析時，以實際量測值 I_s、V、T_l、T_o 與 T_s 值代入公式（19）與（20），可得到 Y_l、X_{1l}、X_{2l} 與 X_{3l} 值。

(6)利用線性迴歸技術，Y_l 爲他變數（Dependent Variables），X_{1l} 爲自變數（Independent Variables）以評估 g_1、g_2 與 K_g 之參數值與各種統計量如 t 值，S.E.（Standard Errors）值。

(7)利用相同技術，計算公式（13）與（15）之各參數值，公式（15）之 n 值分別代入0.5與0.8，並進行比較。

五、模式之比較與驗證：

模式之驗證工作中，利用迴歸分析抉擇模式參數之數據組與驗證用之數據組應彼此獨立，以避免僅是相同數據自身之歸納分析。因此在模式驗證比較中，曾用以進行參數評估所用之數據不再被用以驗證模式之符合性。

模式之符合性其比較基準介紹如下[20,21]

(一)定量方面：

1. 量測值（O_l）與預測值（P_l）之進行迴歸分析，並評估其統計量，完美之預測模式其迴歸係數斜率爲1.0，截距爲0。
2. 標準差：SE（Standard errors）
3. 平均誤差值：Da

$$D_a = \frac{\Sigma |Q_l - P_l|}{N} \quad \cdots\cdots (21)$$

SE，D_a 愈小，模式之符合性愈好。

(二)定性方面：

以量測值與預測值（或量測值）之相異量爲殘差量，描繪殘差對預測值之分佈關係，稱爲殘差圖。理想的殘差圖其特性爲沿 x 軸作均勻之分佈，不具規律性。其分佈帶愈窄代表量化之效果愈理想。

結果與討論

一、參數選擇值：

㈠日照能穿透率

日照能量穿透係數（π）經實測結果，其數值如下：

1. 30g/m² 不織布：$\pi_1=0.88$。

2. 17g/m² 不織布：$\pi_2=0.94$。

㈡熱傳遞係數

經迴歸分析評估係數之結果如下：

1. 30g/m² 不織布

(1)$I_s>150$ W/m²，適用迴歸方程式：

$Y_1=30.2 \cdot X_1+4.16 \cdot X_2$，再改寫爲：……(23)

$Y_1=25.1 \cdot K \cdot (T_i-T_o)+3.47 \cdot K \cdot V \cdot (T_i-T_o)$ ……(24)

$Y_2=33.31 \cdot K \cdot (T_i-T_o)+0.552 \cdot K \cdot V^{0.8} \cdot (T_i-T_o)$ ……(25)

(2)$I_s<150$ W/m²，適用迴歸方程式：

$Y_3=6.83 \cdot K \cdot V \cdot (T_i-T_o)$ ……(26)

2. 17g/m² 不織布

(1)$I_s>150$ W/m²

$Y_4=17.88 \cdot K \cdot (T_i-T_o)+14.67 \cdot K \cdot V \cdot (T_i-T_o)$ ……(27)

$Y_5=22.8 \cdot K \cdot V^{0.8} \cdot (T_i-T_o)$ ……(28)

(2)$I_s<150$ W/m²

$Y_5=4.64 \cdot K \cdot (T_i-T_o)$ ……(29)

由上述統計分析結果可知，土壤熱傳遞 Q_g 時項之數值：$K_g \cdot (T_i-T_s)$，在迴歸分析中因其係數 K_g 並無顯著性（由 t 檢定之結果），因此 K_g 係數並無存在之必要，換言之，土壤熱傳量在不織布浮動型覆蓋栽培時，可忽略此項熱傳。由實際之土溫與氣溫之量測值相差並不大之事實（通常3°C以內），可知土壤熱傳量佔總能量和之比例極小，因此可加以忽略。

二、適用模式之比較

對迴歸模式中，兩種不織布在大於150 W/m² 之大氣狀況下，其適用模式有公式（24）與（25），（27）與（28），利用任選之七天量測數據，比較模式預測能力之適用性如下：

㈠30 g/m² 不織布

1. 以公式（24）對驗證用數據加以進行適稱性分析，預測值（P）與觀察量測值（O）之分佈圖形如圖 2 a所示，殘差圖如圖 2 b。由殘差圖可知此模式定性方面適稱性良好。量化標準如下：

$O=2.56+0.89 \cdot P$，$R^2=0.95$

SE＝1.264，Da＝1.04

2. 以公式（25）之驗證分析中，殘差圖分佈亦爲常態不具規律性，但其範圍較廣。

量化標準如下：

$O=2.78+0.87 \cdot P$，$R^2=0.93$

SE＝1.672，Da＝1.331

由定量標準之比較可知，公式（24）預測能力優於公式（25），平均誤差值（Da）在1.1°C之內，預測標準差（SE）1.3°C以內。

㈡17 g/m² 不織布

1. 以公式（27）之驗證分析中，預測值對觀察量測值之分佈圖形如3a。殘差圖如圖3_b，具有

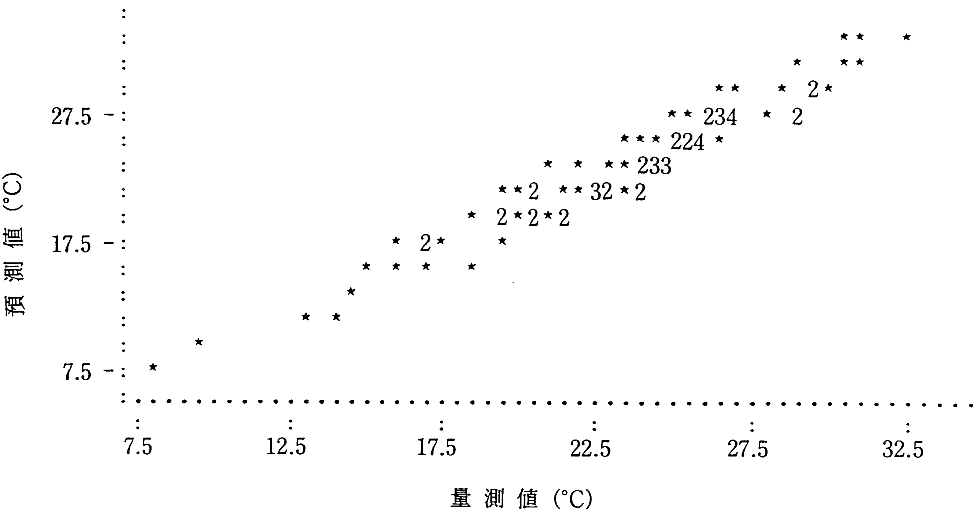

圖2a. 30 g/m² 材料公式 (24) 之預測值與量測值
(圖內數字爲重覆出現之數目)

Fig. 2a. The predictive values and measured values of the equation (24) for 30 g/m² fabrics

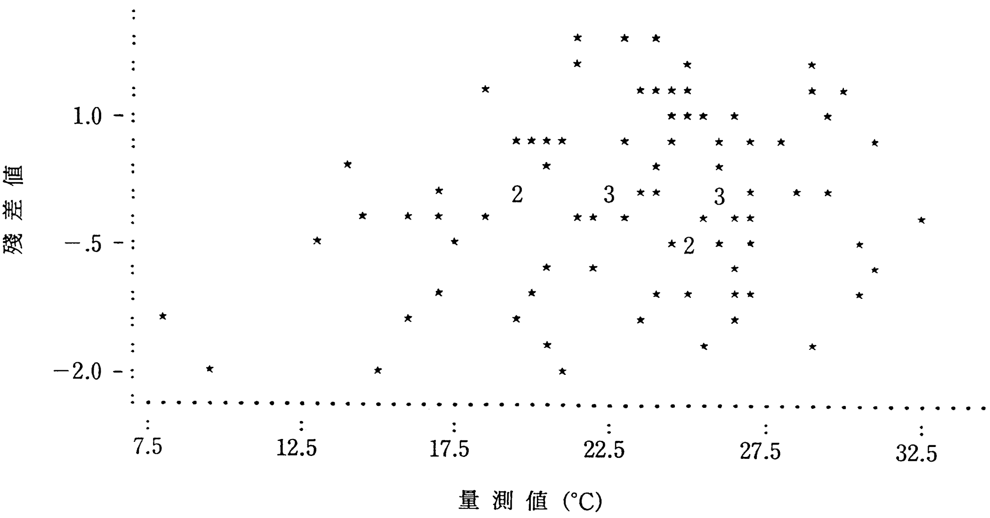

圖2b. 30 g/m² 材料公式 (24) 之殘差圖

Fig. 2b. The residual plots of the equation (24) for 30 g/m² fabrics

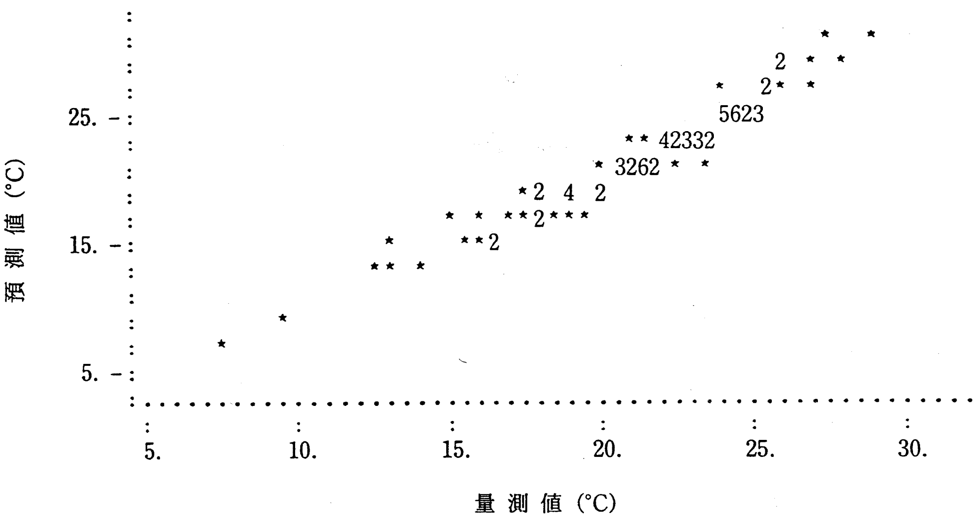

圖3a. 17 g/㎡ 材料公式 (26) 之預測值與量測值

Fig. 3a. The predictive values and measured values of equation (26) for 17 g/㎡ fabrics

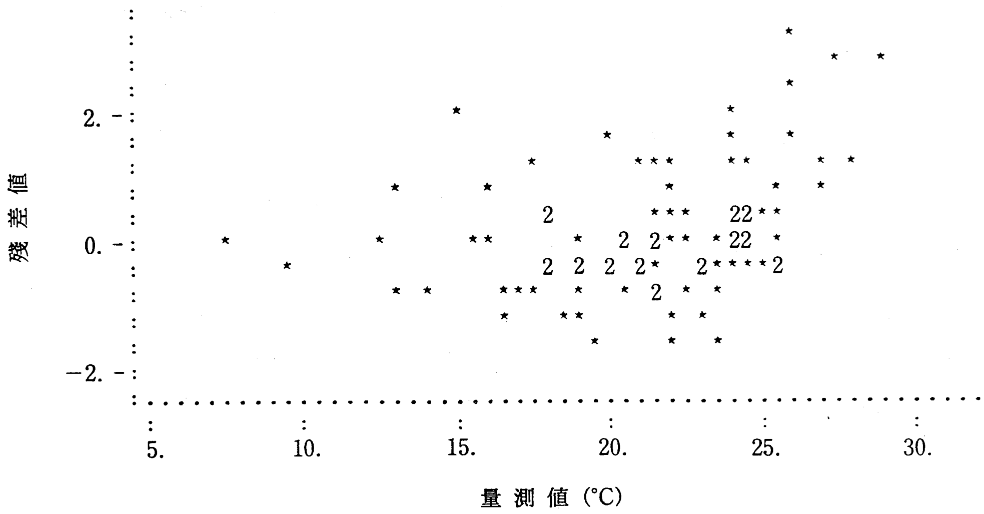

圖3b. 17 g/㎡ 材料公式 (26) 之殘差圖

Fig. 3b. The residual plots of the equation (26) for 30 g/㎡ fabrics

均勻分佈之特性。量化標準中，

$O=2.35+0.884 \cdot P$，$R^2=0.96$

SE=1.01，Da=0.76

2. 以公式 (28) 之驗證分析中，殘差圖具有均勻分佈之特性，定量標準計算如下：

$O=2.78+0.853 \cdot P$，$R^2=0.944$

SE=1.261，Da=0.971

由此可知公式 (27) 之預測能力優於公式 (28) 。

三、不織布浮動型覆蓋之熱環境模式

由模式之適稱能力比較中，不織布浮動型覆蓋之熱環境適用模式描述如下：

(一)30 g/m² 不織布

1. $I_s>150\ W/m^2$

$$\pi \cdot I_s \cdot A_f=25.1 \cdot A_w \cdot (T_i-T_o)+3.47 \cdot A_w \cdot V \cdot (T_i-T_o)+0.7 \cdot \sigma \cdot A_f \cdot [T_{ik}^4-T_{sk}^4] \quad (30)$$

1. $I_s>150\ W/m^2$

$$\pi \cdot I_s \cdot A_f=6.83 \cdot Aw \cdot V \cdot (T_i-T_o)+0.7 \cdot \sigma \cdot A_f \cdot [T_{ik}^4-T_{sk}^4] \quad (31)$$

(二)17 g/m² 不織布

1. $I_s>150\ W/m^2$

$$\pi \cdot I_s \cdot A_f=17.78 \cdot A_w \cdot (T_i-T_o)+14.67 \cdot A_w \cdot V \cdot (T_i-T_o)+0.88 \cdot \sigma \cdot A_f \cdot [T_{ik}^4-T_{sk}^4] \quad (32)$$

1. $I_s>150\ W/m^2$

$$\pi \cdot I_s \cdot A_f=4.64 \cdot Aw \cdot (T_i-T_o)+0.88 \cdot \sigma \cdot A_f \cdot [T_{ik}^4-T_{sk}^4] \quad (33)$$

由此可知影響不織布浮動型覆蓋內部溫度之主要因子為大氣日照量，氣溫與風速，地面傳熱量並不顯著。

四、模式之驗證能力

(一)最高氣溫大於15°C

以典型三組冬日常溫下所量測之不織布覆蓋熱環境溫度數據，描繪其氣象資料與預測曲線如圖4a～4c。

圖4a 中，日照量因雲層影響而不穩定，當日氣溫於18～23°C之間，觀察值與預測值之符合性良好，30 g/m² 不織布覆蓋的保溫效果使內部溫度高於氣溫4～5°C，模式預測最大誤差約2°C。17 g/m² 不織布之保溫能力約2—3°C，預測最大誤差約1.5°C。

圖4b 中，大氣溫度起伏變化大，自18°C至28°C，因外界風力之作用，30g不織布之加溫效果約 3 — 5 °C，17 g/m² 不織布之加溫效果約 2 — 3 °C。模式之預測曲線符合量測值之變化情況。

圖4c 所示大氣情況為晴朗之天候，太陽能量之分佈極具規則，氣溫自早上8°C昇至正午之15°C，此為典型冬日寒流影響下之氣候，風速均在 2 m/sec 以內 (未加以圖示) 。30g/m² 材料之保溫能力高達 7 °C，17 g/m² 材料之保溫能力約 3 — 4 °C。環式之預測能力良好，誤差約在1.5°C以內。

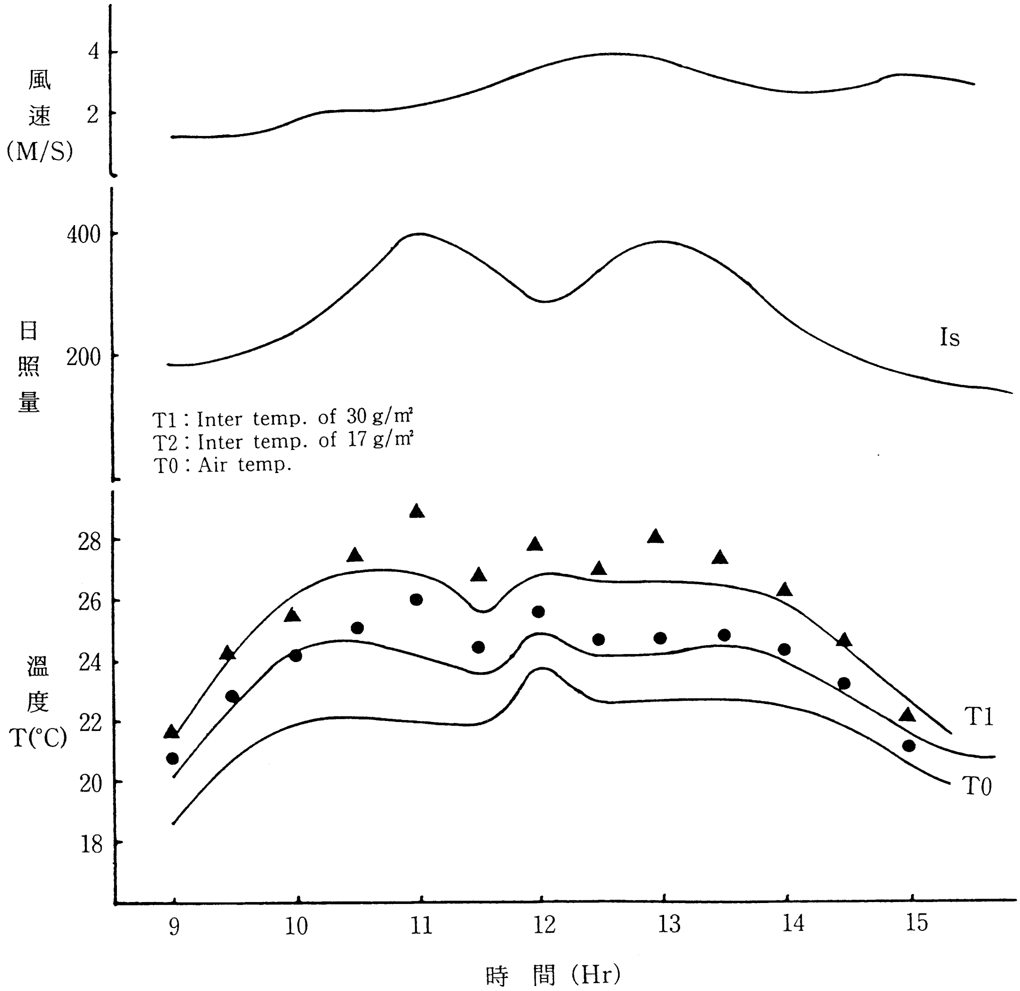

圖4a. 常溫時環境模式驗證

Fig. 4a. Verification of environment model at normal temperatures

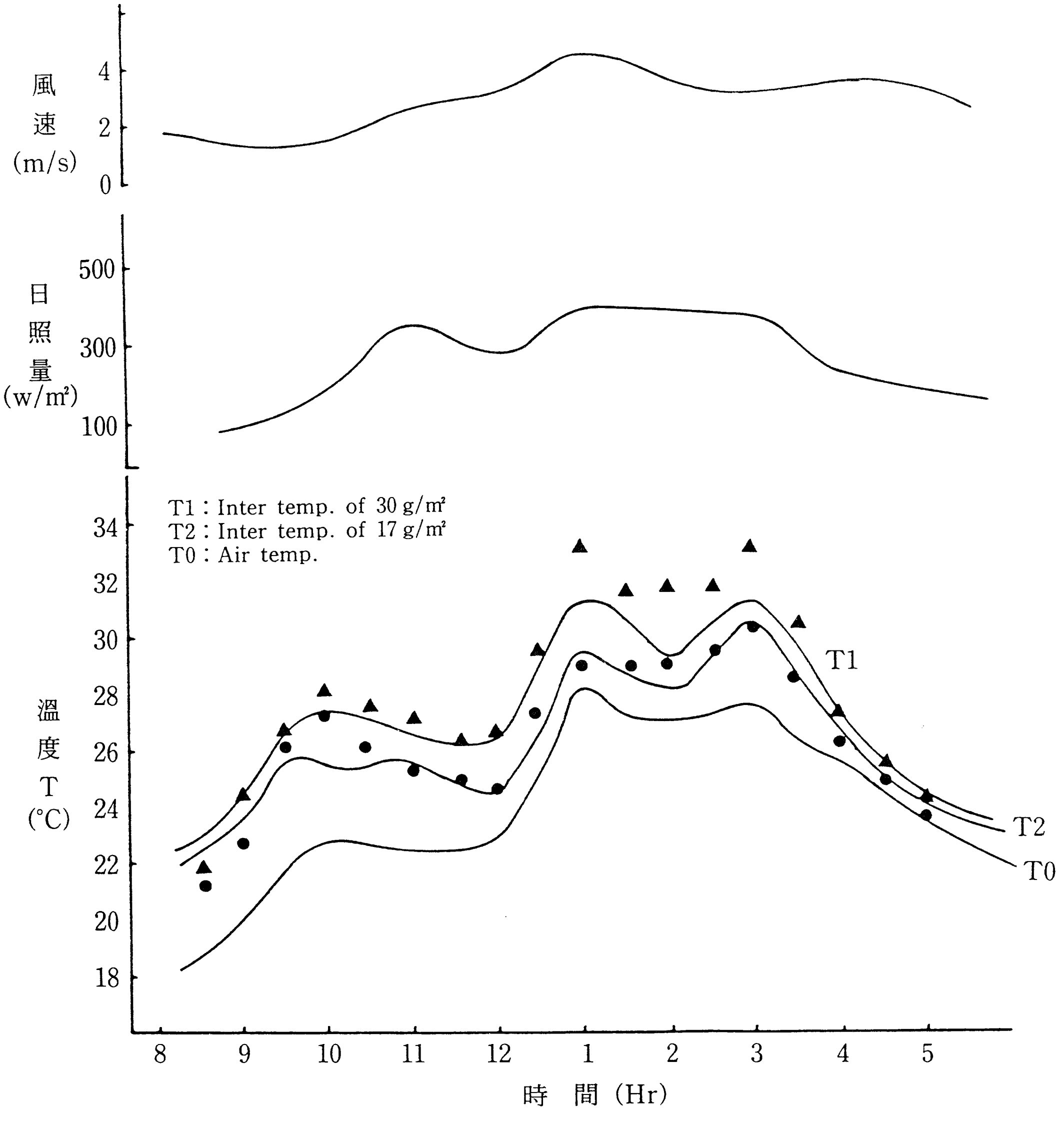

圖4b. 常溫時環境模式驗證

Fig. 4b. Verification of environment model at normal temperatures

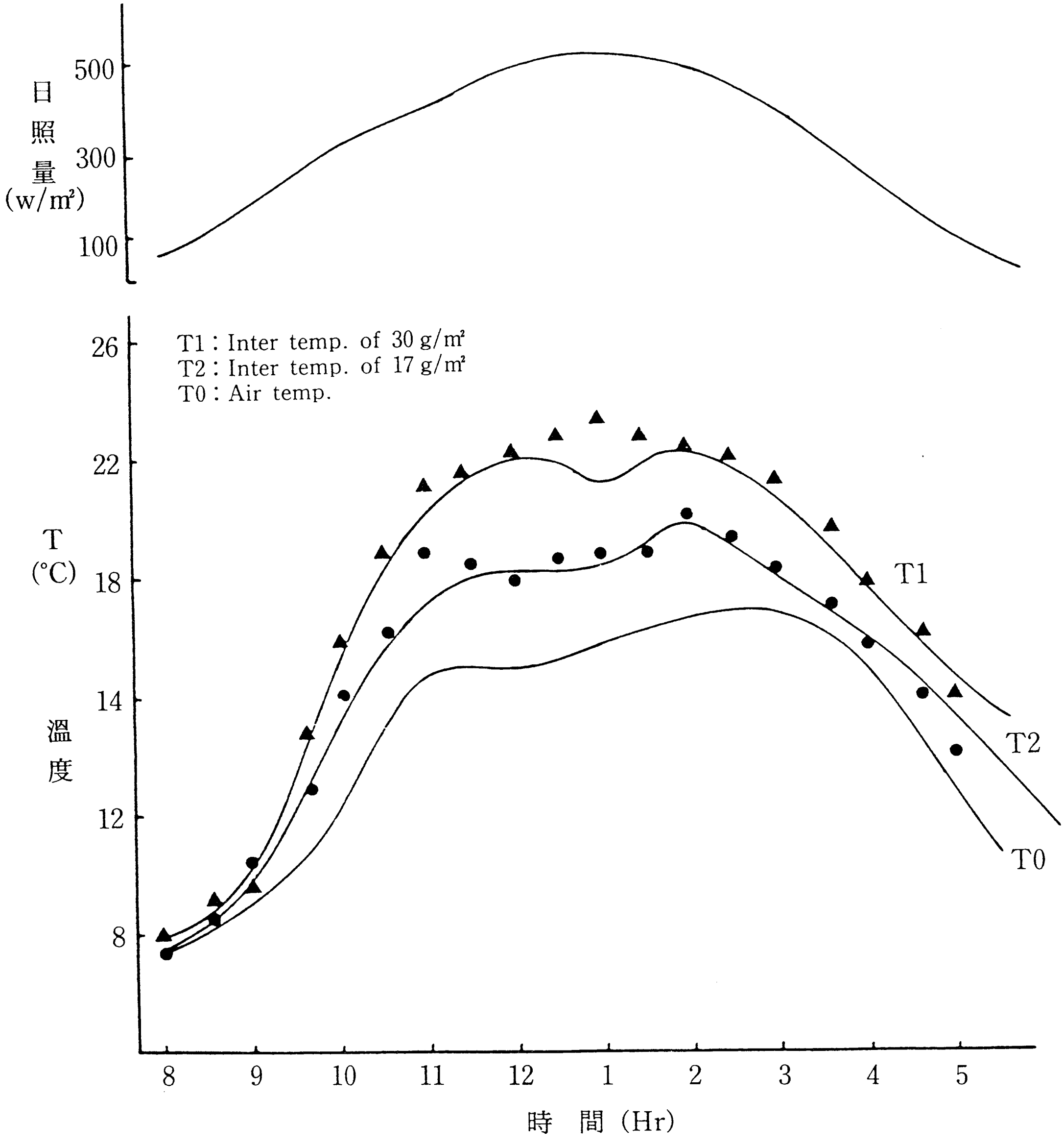

圖4c. 常溫時環境模式驗證

Fig. 4c. Verification of environment model at normal temperatures

㈡最高氣溫小於15°C

在寒流來襲且日照量不高時，氣溫受影響而無法昇高 。圖 5a～5b 代表此種低溫天氣狀況。

圖5a 中當日之日照量皆低於200 W/㎡，最高氣溫低於14°C，風速在2.0m/sec 之內。30 g/㎡ 材料之保溫能力約有3～4°C，17 g/㎡ 材料之加溫能力約1～2°C，模式之預測能力對17 g/㎡ 之材料十分良好，但是對30 g/㎡ 材料而言，下午2～5時之間有高估現象，誤差在1.5°C左右。

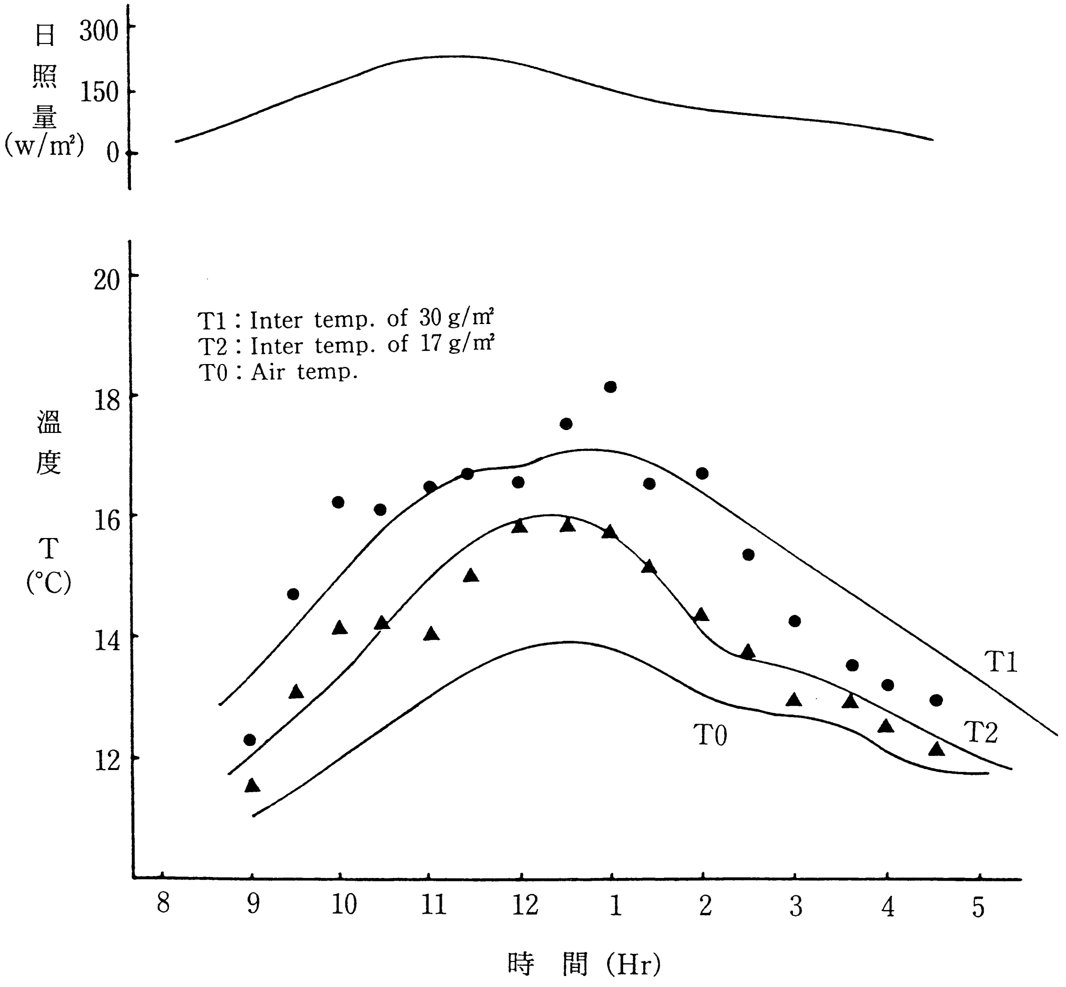

圖5a. 低溫時環境模式驗證

Fig. 5a. Verification of environment model at lower temperatures

圖5b 中，當日之日照量幾乎皆低於150 W/㎡，風速在2.0 m/sec 以上，大氣溫度在14～16°C之間。30 g/㎡ 不織布之保溫效果約高於氣溫2.5°C，17 g/㎡ 材料之加溫能力至1°C以內。30 g/㎡ 材料之模式預測有高估現象，但其誤差均低於1.5°C。

在低日照量下，30 g/㎡ 材料其預測模式有高估現象，其原因可能由於出自熱傳物性在低日照強度下與高日照度狀態下有所差異，需要更詳細之研究加以探討，但此模式在實際應用之

最大誤差約低於1.5°C，已合乎實用要求。

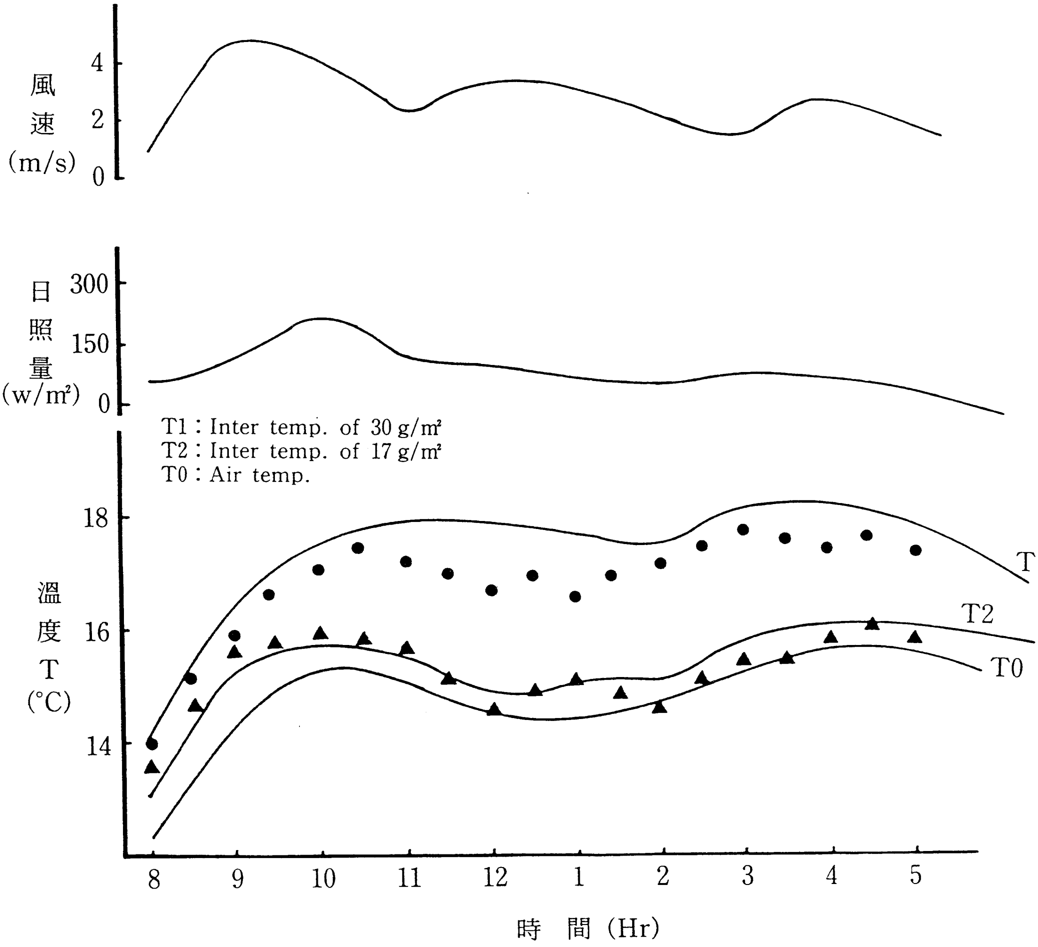

圖5b. 低溫時環境模式驗證

Fig. 5b. Verification of environment model at lower temperatures

五、模式之應用

由上述模式之建立與驗證結果可知，影響不織布浮動型覆蓋栽培內部溫度之主要因子爲大氣日照量，大氣溫度與風速。國內在設施研究中仍僅局限於氣象數據之記錄，而缺乏以量化模式建立其規律性，因此其推廣應用價值有限。經由熱傳原理建立之模式，由於有學理之依據，適用於不同氣候與不同材料之情況。其應用價值即在於此推衍性。對作物栽培而言，熱環境模式之應用價值如下：

(一)由各地區之氣候資料與不織布材料，可用以評估其浮動覆蓋微氣候氣溫之變化。如其他材料如20、23 g/m² 不織布，其溫度分佈即介於兩者之間。

(二)配合作物成長生理資料，栽培者可判斷何型材料可適用其栽培作物，或判斷此種設施栽培方式是否可行，因此可執行合理之生產規劃。

(三)配合作物病蟲發展模式，栽培者可用判別病蟲害發生之機率，發展程度與最適當之防治方式。

國內設施栽培除地面直接覆蓋與浮動型覆蓋之外，圓弧式隧道，高架隧道型與簡易遮雨棚栽培方

式之應用亦逐年增加，其適用模式亦需要建立，此研究方法可提供其他設施參考之用。

結 論

綜合以上研究結果，所得結果如下：

一、利用熱傳原理建立之不織布浮動型覆蓋栽培熱環境模式，其預測能力良好，誤差範圍爲±2°C，平均誤差在1.5°C之內。

二、配合統計之迴歸技術，可用以評估覆蓋材料之熱傳係數，此技術可應用於其他設施模式之研究。

三、影響此型設施栽培內部溫度之主要氣象因子爲大氣日照量，氣溫與風速。

四、配合作物成長資料，此模式可用以進行農作物浮動式不織布覆蓋栽培之生產規劃。

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Study on Thermal Environment Model for Floating Mulches of Non-woven Fabrics[1]

C. C. Chen[2], B. H. Chen[3] and C. T. Tsao[2]

Summary

An analytical thermal environment model is developed to predict the air temperatures under the floating mulches of non-woven fabrics. The values of conduction and convection transfer coefficient of these materials are evaluated by the partly measured data and regression analysis techniques. Reasonable agreement was found between the predicted values and the observed data. The accuracies of predict ability for the model was within 1.5°C. The effect factors for the inner temperatures of covers are the solar intensity, outside air temperature and wind speed.

Key words : Floating mulches, Non-woven fabrics, Thermal environmet model.

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1. Contribution No. 1670 from Taiwan Agricultral Research Institute.
2. Associate Researcher, Junior Specialist.
3. Assistant Researcher, TARI, Wufeng, Taichung, Taiwan 413.

中華農業研究

第四十二卷　第二期

中華民國八十二年六月出版

發行人：杜金池

總編輯：廖慶樑

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Vol. 42, No. 2 June 1993

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統一編號
030853820010

Vol. 42, No. 2 June 1993

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(Formerly Journal of Taiwan Agricultural Research)

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